HABITAT PREFERENCE AND BREEDING BIOLOGY OF GREY FRANCOLIN (*Francolinus pondicerianus*) IN SALT RANGE, PUNJAB

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HABITAT PREFERENCE AND BREEDING BIOLOGY OF GREY FRANCOLIN (*Francolinus pondicerianus*) IN SALT RANGE, PUNJAB

by

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Department of Wildlife Management
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CERTIFICATION

I hereby undertake that this research is an original one and no part of this thesis falls under plagiarism. If found otherwise, at any stage, I will be responsible for the consequences.

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LIST OF ABBREVIATIONS

AIC	Akaike information criterion
ANOVA	Analysis of variance
°C	Degree Celsius
CI	Confidence interval
Cm	Centimeter
E	East
ESW	Effective strip width
Gm	Gram
GOP	Government of Pakistan
IVI	Importance Value Index
IV	Ivelv's electivity Index
L	Length
LSNP	Lal Suhanra National Park
N	North
RD	Relative density
RF	Relative frequency
RCo	Relative Cover
SD	Standard Deviation
W	Width

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ABSTRACT

Grey francolin (*Francolinus pondicerianus*) belongs to Order Galliformes and Family Phasianidae. It is a medium sized game bird, considered a friend of the farmers as believed to consume insects, their eggs and larvae which are harmful to crops, hence, serving as biological control agent. Populations of grey francolin have declined over the time mainly due to excessive hunting and habitat destruction. Research studies have not been carried out on Grey francolin in the Salt Range and data on their biological and ecological aspects is lacking. The present study was conducted in two protected areas i.e. Chumbi Surla Wildlife Sanctuary (CSWS) and Diljabba Domeli Game Resrve (DDGR) to generate information about preferred habitat, feeding habits, population density, distribution pattern and breeding biology, including breeding season, nest structure, clutch size, incubation period and hatching success in the Salt Range. Four habitat types were selected and compared for habitat analysis study. These included: Habitat I- cultivated crop fields and associated natural vegetation on field boundaries; habitat II- natural forest and associated grassland; habitat III - open land; and habitat IV- wetlands and associated natural vegetation. Through vegetation survey, 38 plants species were recorded from CSWS; among those seven were trees, five shrubs, 15 herbs, nine grasses and two cultivated crops. Thirty four plant species were recorded from DDGR, including six trees, five shrubs, 14 herbs, seven grasses and two cultivated crops. The preferred habitat of Grey francolin found in both study areas (CSWS and DDGR) was Habitat-II that was natural forest habitat with highest IVI values for trees, shrubs, herbs and grasses. In addition to this, other

variables such as elevation, slope, aspect and water availability were also considered for habitat preference by Grey francolin. In CSWS, Grey francolin showed high preference for the habitat having Ivelve's value (IV) of 0.26, an elevation of 697 m to 704 m, a slope of 25 º to 55 º, with open aspect (without dense vegetation cover) and where water was available. In DDGR, high preference was shown by Grey francolin for habitat having elevation from 505 m to 523 m with aspect that was not very close and slope of 25 º to 45 º with water availability having Ivelve's value 0.19. Dominant tree species in all selected habitats were *Acacia modesta, Acacia nilotica, Dalbergia sissoo,* and *Olea Cuspidata,* dominant shrub was *Ziziphus jujuba* and grasses were *Andropogon contortus*, *Desmostachya bipinata* and *Cynodon dactylon.* Plant species used for roosting by Grey francolin included *Acacia modesta, Acacia nilotica* and *Ziziphus jujuba* in CSWS and *Dilbergia sissoo, Acacia modesta* and *Ziziphus jujuba* in DDGR. For population estimation of Grey francolin, 40 transects were laid in the both areas and Grey francolin population were recorded both by direct sighting and calls and data was analyzes by DISTANCE Software 6.0. There was significant difference in population densities among different sites both by sighting and calls method. In CSWS, population density by sighting was the highest at Open land habitat (3.23 individual ha^{-1}) while lowest at cultivated habitat (1.58 individual ha^{-1}) and by calls was the highest at (2.87 individual ha^{-1}) from natural forest habitat, while lowest at (1.59 individual ha^{-1}) from cultivated habitat. In DDGR population density by sighting was highest from wetland (2.47 individual ha^{-1}) and lowest at (2.09 individual ha^{-1}) from natural forest habitat, by calls highest from open land habitat (2.45 individual ha^{-1}) and lowest from wetland habitat (1.10 individual ha^{-1}).

Breeding season for the Grey francolin in the study area extended from mid March to end of July. All the nests located during the study were found on the ground in natural vegetation consisting of *Acacia modesta*, *Acacia nilotica*, *Ziziphus jujuba*, *Dalbergia sissoo*, *Desmostachia bipinnata* and *Cynodon dactylon*. Shape of nest varied from round to elongate. Outer and inner diameter of grey francolin's nest in cultivated and natural forest habitat did not differ significantly. However, egg length, width and volume were higher significantly in cultivated habitat versus forest habitat. Color of the egg was dusty white to pink with white spots on it and texture was somewhat rough and smooth, while shape was oval in both habitat types. Out of a total of 68 eggs located in various nests, 53 hatched (74.80%) with a mean hatching rate of 5.3±0.85 eggs per clutch. The fledging success was estimated at 4.6±0.81 per clutch (77%).

Data on threats to Grey francolin habitat and population were collected through questionnaire survey from hunters, local people and wildlife staffs. Major threats affecting grey francolin in both CSWS and DDGR were identified as hunting, trade, habitat destruction, predation, livestock pressure, agriculture activities, fuel wood collection, land clearing and stone crushing. Major threat to Grey francolin populations and habitats reported in CSWS included: 38% illegal hunting ;18 % agriculture activities; 18% land clearing; 06% by trade; 06% habitat destruction; 04% predation; 04 % live stock pressure; 04% by fuel wood collection and 02% due to stone crushing. Similarly major threat to Grey francolin reported by respondents in DDGR were: 46% illegal hunting; 18 % agriculture; 16% fuel wood collection; 04% trade; 04% predation; 04 % live stock pressure; 04% land clearing; 02% habitat destruction, and 2% due to stone crushing. This study

generated information about the preferred habitat, population density, distribution pattern and breeding aspects of Grey francolin in the study area and identified major threats affecting grey francolin's population in the study area that provide baseline data for the conservation of Grey francolin, ultimately helping to sustaining the population of this important game bird in the Salt Range. Results of the study suggested that the Grey francolin is successfully breeding in the study area and that is mainly associated with natural vegetation and crop cultivated fields around natural areas, which supports its population in Salt Range.

Chapter 1

INTRODUCTION

1.1. GENERAL INTRODUCTION

Pakistan has variety of ecosystems with diverse avifauna to exploit their resources (Khan *et al*., 1996). More than 650 bird species have been reported in the country and their occurrence is unique in the world (Grimmett *et al*., 2008; Mirza and Wasiq, 2007). Order Galliformes contains fowl-like birds. Species in this group are characterized by heavy bodies, strong feet, short heads, often small bills and wings, and sharp horny spur present on the back of each leg in adult males of some species of family Phasianidae such as *Francolinus pondicerianus*. Important game birds such as partridges, grouse, pheasants, turkeys and quails belong to this order. This is distinct group ecologically, and characterized by having single species or group of species in all parts of the world with exception of arctic forests, extreme part of Sahara desert in Africa and cold region (Fuller *et al.,* 2000). Galliformes includes the majority of game birds that are important both economically and socially and some of these species have been hunted for many years (Harris and Pimm, 2007; McGowan *et al.*, 1995). Historically, birds belonging to this order have been known as game birds and for food (Grzimek *et al*., 2004).

The genus Francolinus belongs to Order Galliformes and Family Phasianidae and is diverse genus of medium-sized game birds that comprises of 41 species (Dickinson, 2003), two of which reach West Palearctic region (which are mainly Afri-

can), with a few species in Southern Asia (Cramp *et al*., 1983). The term partridge is used globally and comprised of 53 species (Viljoen *et al*., 2004; Crowe *et al.,* 1992). The francolin is used often to distinguish a group of birds from the partridges having slim built and relatively erect posture of body (Crowe and Little, 2004). Asia is the origin of grey partridge (*Perdix perdix*) from where it established itself with the spread of agriculture into Europe, extending its range in the sub-region of Euro Mediterranean (De Leo *et al.,* 2004).

Francolins have both positive and negative economic importance. An essential role has been played by many species of this group in the maintenance of ecosystems. These are seed predators and thus help in the spread of plant species, ultimately allowing the normal food chain to proceed in smooth manner (IUCN, 2003). Some of these species are important for ecotourism while others such as grey and black francolins have been kept as pet birds and reared for meat and eggs for utilization by human (McGowan, 2002). At places, they harm young shoots and pick seeds, so are destructive for agricultural crops (Dickinson, 2003). Both the hunters and nature lovers have attraction for all species of francolins as they remained as cherish game birds for them (Fuller *et al*., 2000). Being used in cockfighting, they are also considered as entertainment source, especially in the southern part of the Punjab and Khyber Pakhtun Khwa provinces of Pakistan. At village fairs, this tradition is still common (Javed, 1991).

1.2. ECOLOGY OF GREY FRANCOLIN

Grey francolin (*Francolinus pondicerianus*), formerly called grey partridge is

found in open, dry and arid parts of the Asia (IUCN, 2013): Pakistan, south-eastern Iran, India, Bangladesh and northern Sri Lanka. It is a typical grassland game bird found in the plain, largely treeless areass. Its origin allowed it to live easily in crop fields, where it can find cover, food, and ground for nesting (del Hoyo *et al.*, 1994; Fuller *et al.*, 2000).

Grey francolin (*Francolinus pondicerianus*), is native bird of Pakistan (Ali and Ripley, 1983; Roberts, 1991; Islam, 1999); however, under different environmental conditions shows seasonal local movements upto 81 km. Grey francolin is somewhat larger than black francolin (*Francolinus francolinus*) in size having 33-35cm body length (Roberts, 1991; Islam, 1999). The sexes are alike in plumage, upper parts of the body are grayish-brown, boldly streaked with pale buff and finely barred with black and chestnut (Plate 1.1). Under parts are buff, prominently barred with black; outer rectrices chestnut. Throat is buff, outlined by a narrow black band, creating a gorget. The outer tail feathers are crossed barred brown and pale - buff. The bill is dark gray, iris hazel, legs and feet dull red and its wingspan is 48-52 cm (Roberts, 1991). Juveniles are without black necklace and head pattern is less conspicuous in them. The immature birds have paler throat-patch, totally enclosing black border and are minor rufous on forehead. Chicks in coloration are light grey (Fuller *et al.*, 2000) (Plate 1.2). Sexes are indistinguishable in coloration in the field but males can be distinguished from females by the presence of metatarsal spur and larger mass (Islam, 1999).

Grey partridge (*Perdix perdix*) has played a prominent part in shooting and hunting from the past (Bro *et al.*, 2000). According to Khan (1997), grey francolin is

an excellent game and delicious table bird, also used as a cage and fighting bird. They are generally found in open farmlands as well as in sparse woodland forests where shrubs are dominant and based on their calls, are commonly calledas 'teetar' (IUCN, 2013; Birdlife International, 2012). It is also reported that grey francolin inhabits wide array of arid habitats from semi-desert grasslands and thorny scrub to tropical thorn forests, sometimes also found in frequent crop field areas and villages (de Hoyo *et al*., 1994). It is generally found below 610 m but occasionally as high as 1400 m (Roberts, 1991).

Despite continuous persecution by hunters and bird trappers, grey francolin (*Francolinus pondicerianus*), seems to be able to survive in proximity to man (Roberts, 1991). They are noted as pugnacity and can easily be attracted by a captive call bird and netted. They are extremely popular as cage birds partly because of their loud and ringing call. They have one of the most familiar bird calls in the rural areas (Roberts, 1991). Legge (1880) describes its call varied by a more lively call like ka-tee klar-ka, ka-tee klar-ka and it relates the click ke-augh-ke-augh with certain repetition. In pair forms, male and female are known to interact with each other by their notes and sounds like kateela, kateela, kateela by producing a musical call (Ali and Ripley, 1983). When alarmed, their call is a whirring khirr-khirr (Roberts, 1991) but pairs also make communication in a 'unsual, complain sound' (Henry, 1971). In the Sub-continent, grey francolin (*Francolinus pondicerianus*), has remained as the popular game bird and has been constantly hunted as their meat is considered an economical source of protein to the local inhabitants (Long, 1981).

In Pakistan, Grey francolins (*Francolinus pondicerianus*), avoid intensively cultivated and heavily populated areas and are most plentiful in undisturbed tropical thorn forest habitat. It is much better adapted to arid conditions than black francolin (*Francolinus francolinus*) and it is a widespread game bird of agro-silvicultural systems of Pakistan (Roberts, 1991).

Daily movements of grey partridge (*Perdix perdix*) are quite limited and concerned mostly with daily routine activities such as securing food, dusting and resting. In the fall and winter, the coveys move to an area where weed seeds, cereals, grits and moist vegetation are available. Shortage of any of these necessities will cause the coveys to leave the area (Gould, 1966).

The Grey francolin (*Francolinus pondicerianus*), is omnivorous in feeding habits (Chaudary and Bhatti, 1992). They analyzed 36 stomachs in Khanewal (Pakistan) and found them utilizing both plants and insects. Stomachs from 10 grey francolins taken between March and July at Faisalabad area contained grains, seeds, weed seeds, vegetable matter, locust hoppers, ants, termites and beetle grubs (Roberts, 1991). Hussain *et al*., (2012), reported that in Pothwar area grey francolin prefers seeds, grains, ants and termites in cultivated fields and croplands. Similarly, Mian and Wajid (1994) concluded that in Layyah district of Punjab (Pakistan) during winter, grey francolin were dependent upon insects (9.8 percent), mature seeds of at least 16 plant species (69.63 percent; mainly *Potamogeton filiformis, Vigna radiata, Asphodelus tenuifolius, Triticum aestivum*) and leaves (21.27

percent). Non-significant differences in food composition were recorded between the sexes.

According to Legge (1880) grey partridge (*Perdix perdix*) feed on insects, mostly grasshoppers both in young and adult stages. They can be seen scratching the soil and digging the ground for insects with their feet and bills. Even at times for food, cattle dung is pecked (Ali and Ripley, 1983). Johns (1980) found that young partridges especially feed on ants and their pupae or larvae, but, they also feed on weeds, green leaves and cereals besides insects.

The grey partridge (*Perdix perdix*) plays a significant role in natural food webs. Foxes and crows predate on this species at egg, juvenile or adult stages (Tapper *et al*., 1996). Weigand (1977) reported that raptors are the main predators of adult francolins, although red fox, coyotes and weasels also prey on adults. Since insect based food constitutes a significant part of the diet of grey francolin (Faruqi *et al*., 1960; Mian and Wajid 1994), therefore, they play a role of biological control agent of insect pests in agro-ecosystems.

They may roost at night on low thorny branches of trees or shrubs in pairs or family groups called “coveys” and have camouflaging plumage to live in vegetation that is not so dense (Sharma, 1983; Roberts, 1991). Grey francolins (*Francolinus pondicerianus*), form a monogamous pair bond, but females do all the incubation. Nesting is mostly in spring, eggs being found in March and April, but a few pairs nest in September and October after the monsoon rains. The eggs are glossy,

pointed at one end and vary from pale brownish to pale buff and are unmarked. Incubation takes 18 to 19 days and the chicks hatch synchronously. Both parents tend the chicks after hatching (Roberts, 1991).

Grey partridge (*Perdix perdix*) is found in western Asia, across Europe, northern United States of America and in some parts of south Canada (BirdLife International, 2012; Dumke *et al.,* 1980; IUCN, 2013; De Leo *et al.,* 2004). Grey francolin has a vast distribution range thought to be around 10,000,000 km² (BirdLife International, 2012; IUCN 2013). In 1970's, Grey francolin was introduced in the United Arab Emirates and in twentieth century in Oman. Now, it is successfully established there due to its prolific breeding potential (Khan *et al.,* 2009; Gallagher and Woodcock, 1980).

In Pakistan, Grey francolin (*Francolinus pondicerianus*) is widely distributed from the Indus valley in the west to foothills of the Himalayas in the south. It occurs throughout Lasbela and lower hills of Makran districts in Balochistan, Thar desert of Sindh, Salt Range, Pothwar Plateau and Thal desert of the Punjab and around Cherat and in parts of Kohat districts of Khyber Pakhtun Kwa. They avoid higher hills and are absent around Quetta, but share the same habitat with the See-see partridge (*Ammoperdix griseogularis*) in Kohat, Cherat and Salt Range. They share the same habitat with black partridge in irrigated plantations and outer slops of the Margalla hills (Roberts, 1991). The presence of grey francolin is also reported around Mangla Reservoir in Azad Jammu & Kashmir (Mahmood *et al*., 1997).

Grey francolin is rarely found above an elevation of 1200 m in Pakistan and usually found feeding on bare soil or low grass cover in open and scrub country (Rasmussen and Anderton, 2005). Ali (1945) reported that grey francolin is common and abundant in Run of Kutch area (Pakistan) and outside the Kutch it is found throughout the drier portion of India.

The decline of grey francolin (*Francolinus pondicerianus*) population has been reported in the past, with the species as an indicator for farmland ecosystems and as a game bird (Chaudhary and Bhatti, 1992; Islam, 1999). Increased use of pesticides caused by the agricultural expansion and habitat degradation can be cited as the main causes behind its decline. A rapid decline in its natural habitat has been reported by Roberts (1991), through its food loss, excessive predation, habitat destruction, intensification of agricultural practices and pressure on scrub forests for use as fodder, timber wood and fire wood needs. The grey francolin seen an overall decline in its population as high as 79% during the last 10 years. It is listed as Least Concern on IUCN Red List, primarily because it has a wider distribution range (Birdlife International, 2012; de Hoyo *et al*., 1994).

Unfortunately, in the past very few studies addressed grey francolin found in different parts of Pakistan. None of those was carried out in Salt Range of the Punjab, one of the major areas of its distribution in Pakistan. Keeping in view the declining trend in population of grey francolin, the current study was conducted in Salt Range. This study generated information about preferred habitat, population density, distribution pattern in different habitat types and breeding aspects including; breeding

season, clutch size, incubation period and hatching success of grey francolin in the study area. It would provide essential scientific base required for the conservation of grey francolin, ultimately helping in sustaining the population of this important game bird in Salt Range. The study was conducted with the following objectives;

1.3. OBJECTIVES

1. To determine the preferred habitat of grey francolin in Salt Range.

2. To estimate population density of grey francolin in selected habitats of Salt Range.

3. To describe breeding biology including; breeding season, nest structure, clutch size, incubation period and hatching success of this species in the study area.

4. To identify the natural as well as anthropogenic factors that affect the habitat and population of this bird in the study area.

Chapter 2

REVIEW OF LITERATURE

2.1. HABITAT

Habitat is essential for an animal species as it provides shelter, food and water, the three basic demands of life and hence, each species exists within particular conditions of habitat, depending upon its needs and potential to survive (White and Garrot, 1990). The selection of habitat by a species is a hierarchical process and is different across animal species (Kotliar and Wiens, 1990), which make habitat studies difficult (McGrath *et al*., 2003). According to Aebischer (1997), grey partridge (*Perdix perdix*) is a common game bird of temperate plain grasslands of Asia and Central Europe. The abundance and distribution of grey francolin (*Francolinus pondicerianus*) seem to be largely affected by habitat characteristics such as canopy and, thickness of vegetation, variety of land cover, soil moisture content and, easy access to food (Wijeyamohn *et al*., 2003).

In India, grey francolin occupies open ground, dotted with scrub jungle, border by water, near crop fields (Eriyagama, 1961). Similarly, under the ecological conditions of Faisalabad (Pakistan), cropland and sandy scrub were the most suited habitats for grey francolin while cropland along the wetland proved to be worst habitat for this species (Ullah, 1991). It was observed by Sharma (1983) and Roberts (1991) that thick, sharp and spiny vegetations are selected by the grey francolin in pairs or family groups to roost during night time, which suggest that spiny vegetation is essential for this species.

A study in Europe by Aebischer and Kavanagh (1997) revealed that grey partridge (*Perdix perdix*) preferred open habitats, less severe, diverse farmlands consisting of small fields surrounded by edges and grasslands. According to Hussain *et al*., (2012) grey francolin (*Francolinus pondicerianus*), showed strong association with *Acacia spp*. in Pothwar area (Pakistan). They do not prefer to live under swampy areas and dense vegetation (Khan, 1997). According to Ullah (1991), grey francolin (*Francolinus pondicerianus*), selected to sit on branches having few leaves in summer, but preferred the branches having more leaves in winter. He also mentioned that spiny trees such as *Acacia nilotica* and *Zizyphus jujuba* were selected for roosting in Faisalabad. Similarly, in a study conducted in Sri Lanka by Wijeyamohn *et al*., (2003), it was concluded that habitat having bushes close to ground, xerophytic spiny scrub and cluster of short growing trees consisting mainly of *Acacia eburnean* was preffered by the grey francolin.

Johnsgard (1973) reviewed the habits of grey partridge (*Perdix perdix*) population in North America indicating that this bird inhabited and fed in croplands, particularly small grains and corns in association with native grasses, weedy herbaceous cover, and hayfields. It also occurs in intensive cereal ecosystems in France (Bro *et al*., 2003). An important constituent of habitat necessity of grey partridge (*Perdix perdix*) contains either dominant blooming vegetation such as arid fields or extensive managed and unmanaged grounds or hedgerows as some particular habitats or scattered shrubs with border of managed land and grass layer (Meriggi *et al*., 1990).

Grey francolins (*Francolinus pondicerianus*), are better associated with areas in Rawalpindi district where farmland was enclosed by low scrub forest and sandy wetlands, and avoid marshy fields and thick vegetation (Whistler, 1930). Population density of grey francolin in Pothwar area was found considerably higher in morning than evening hours and also showed seasonal fluctuations during the study period (Mahmood *et al.*, 2010). Hosking and Newberry (1944) concluded that grey partridge (*Perdix perdix*) prefers patches of grass, thin scrub or bush jungle in between cultivated areas and is quite common in crop lands. Similarly in a study conducted by Henry (1971) in Ceylon (Sri Lanka) it was observed that grey francolins (*Francolinus pondicerianus*), are found in scrub lands, hedge rows, pastures dotted with clumps of bushes.

In Hawaii, grey francolin (*Francolinus pondicerianus*), is associated with shrub lands, savannas and coastal kiaw forests in dry, low elevation areas, avoiding brushy understory (Islam, 1999). They are often seen on well watered, human altered environments such as golf courses and lawns; occurs from sea level to 1000 m elevation and generally observed on roadsides at beginning or end of the day (Scott *et al*., 1986; Pratt *et al*., 1987).

2.2. POPULATION

The Galliformes are mostly specialized ground dwelling birds of dense vegetation, and ecologists who study about their population have been handled with troubled to the known population estimation techniques subjecting to the bird species belonging to this group. Transect or quadrate methods of population estimation hardly

work for francolins as obervation of these cryptic birds in the thicker vegetative cover is difficult (Sankaran, 1994; Iqubal *et a*l., 2003). Additionally, daily habits show differences between season and species, and hence become difficult to compile reasonable transect data of sighting (McGowan *et al.,* 1996). Males of these species produce calls during breeding season, hence, most of the studies have used call counts from a permanent point or along a transect to estimate the population density (Kaul and Howman, 1991; Bibby *et al.*, 1992; Nijman, 1998; Panek, 1998; Kaul and Shakya, 2001; Urfi, 2004; Mahmood *et al.,* 2010; Khan, 2010: Urfi *et al.,* 2005). The call count method is though generally used as per its ease, yet deviation of the calling bird usually affects the results (Young *et al.,* 1987) and hence, is not very dependable. Overestimation of bird population is usually caused by call count method, as the bird populations mostly leans toward males (Islam and Crawford, 1993; Donald, 2007). The dual calculation of same bird calls also counts to such overestimations (Howman and Garson, 1993). Ralph and Scott (1981), Bibby *et al*., (1992) and Urfi *et al*., (2005) reported that both sighting / and or call count methods have their own advantages and disadvantages as they used these techniques to record the birds while walking along a permanently established transect line in various habitat types.

For population estimation studies of many francolin species, transect sampling and call count have been utilized in combined form (Howman and Garson, 1993; Abbasi and Khan, 2004, Mahmood *et al*., 2010; Khan, 2010; Hussain *et al*., 2012) to reach at some reasonable estimation of populations. Call counts in spring season were considered more dependable sign to record the breeding pairs/ birds in population of

grey partridge (*Perdix perdix*) (Weigand, 1977), though such estimates were not considered reliable for other parts of the year.

Population density recorded in a study conducted by Ullah (1991) using call count method in wetland and farmland of Faisalabad (Central Punjab, Pakistan), suggested average density of 150 (range 80 – 250) birds/ km^2 for grey francolin (*Francolinus pondicerianus*). Another study carried out in Lal Suhanra National Park recorded grey francolin in relatively very low densities of 0.83 and 0.60/ km^2 in long secured desert tracts (Mian and Ghani, 2007). The density estimates calculated from sightings and call counts reported a difference in estimation as parts of the day and during different seasons by Khan (2010), where grey francolin population density was 6.20±1.52 birds per km^2.

Population density of grey francolin was estimated using line transect method and call count methods in Lehri Nature Park in district Jhelum, Pakistan by Mahmood *et al*., (2010) in three habitat types, where average population density of 0.47±0.09 per hectare was observed. During this study, comparatively higher population density of 1.74 birds/ hectare) was found in the morning time as compared to 0.85birds/ hectare in the afternoon. Hussain *et al*., (2012) estimated the density of grey francolin in agro-ecosystem of Pothwar plateau as 1.59 ± 0.39 birds/ hectare in crop fields and 0.87 ± 0.14 birds/hectare in natural vegetation. In Idaho, Mendel and Peterson (1980) estimated 0.84 grey partridge per hectare. Ratti *et al.,* (1983) reported 0.48 grey partridges/ hectare in South Dakota while Rotella *et al.,* (1996) reported 0.29 grey partridge /hectare in eastern Washington. According to Rotella and Ratti (1986), call

counts of grey partridges in the morning gives a more reasonable estimate of density than call counts in the evening, indicating that early morning call counts may be more reliable for estimating population of grey partridge (*Perdix perdix*). Rotella and Ratti (1988) observed calls as well as calling groups of grey partridges in large number during morning time than that in the evening during summer and winter seasons.

2.3. BREEDING BIOLOGY

2.3.1. Breeding Season

Grey francolins (*Francolinus pondicerianus*), are typically found in pairs but family parties or coveys of 4-8 birds are also known, which break up into pairs in the breeding season (Grimmett *et al*., 1998). Potts (1986) reported that both male and female grey partridge breed during first year after hatching, but pairs are established when female chooses a male. These pairs remain together for whole life. However, since mortality of the mates was common, both sexes readily remate (Carroll, 1993).

Trippenses (1948) reported the breeding season of grey partridge (*Perdix perdix*) extending from March to June, while Waite (1948) and Henry (1971) reported that grey francolin breeds during May, August and December. In Faisalabad (Pakistan), its breeding season extended from March to September, however, large numbers of eggs were recorded in March and June, and maximum numbers of fledglings were reported in April to June (Ullah, 1991).

In Pothwar area (Pakistan), grey francolin (*Francolinus pondicerianus*), breeds between end of March and mid of June (Hussain *et al.*, 2012). In Rajasthan (India),

grey francolin has been reported to build nests in February-April and July-October in its native range, however, it breeds in Kutch area from February to May and occasionally again in August and September (Sharma, 1983).

2.3.2. Nest Construction

Nest of grey francolin always well concealed inside a clump of grass growing up through a thorn bush and it is only a deep bed on the ground, into which a few dead leaves blades are added by the female (Roberts, 1991). Similarly, Hosking and Newberry (1944) stated that nest is scarped in ground, lined with a little grass or a few leaves. Mostly eggs are laid on the bare ground. The camouflage coloration provides protection to the eggs while hen sits on them. Ali (1945) reported that nest is a simple grass lined with scarps on the ground in grassland, standing crops or scrub jungle. Bro *et al*., (2004), observed grey partridge (*Perdix perdix*) clutches in the maize crops, which indicates that species also breeds in agricultural vegetation. Predation for this species' eggs and chicks can be assumed higher as they made their nests on grounds (Potts, 1980; Novoa *et al.,* 2002; Putaala and Hissa, 1998). The management of habitat did not have dominant affect on the breeding season in them. Hatchling in the grey partridge during the first three weeks of their life has more chance to die, while female mortality becomes highest during incubation (Bro *et al*., 2005).

Sharma (1983) reported that grasslands and ploughed fields, and *Euphorbia spp*. were selected as nest sites by grey francolin during breeding season. According to Hussain *et al.*, (2012), nests of grey francolin are mostly made with *Desmostachia bipinnata, Acacia modesta, Ziziphus jujuba, Euphorbia spp.* and *Imperata cylindrica*

in agro-ecosystem of Pothwar Pleatue, Pakistan. Johnsgard (1973) reported nests of grey partridges (*Perdix perdix*) in North America under some protective cover inside shady area for temperature modulation. However, there are reports that in India a nest was found in stacked pile of sorghum less than 1.5m above the ground (Bump and Bump, 1964).

2.3.3. Incubation Period

Incubation is exclusively accomplished by the female in grey francolin (Islam, 1999) and incubation period lasts for 18-19 days. When she incubates, the male remains close and gives alarm calls upon detecting threats (Johns, 1980). Hussain *et al.,* (2012) reported the incubation period of grey francolin in Pothwar region of Pakistan from 19 to 22 days. Bump and Bump (1964) reported that grey francolin incubated eggs in 18 to 20 days in Washington State on west coast of USA. While 18 to 19 days of incubation period in grey francolin was also reported in Delhi and Karachi areas (Ali and Ripley, 1983; Roberts, 1991).

2.3.4. Clutch Size

Clutch size depends on food availability; for example in Rajasthan (India) clutch size was generally larger at agricultural farms, where there was abundance of grain and insects than in scrub jungle and possibly three clutches per season were reported by Bump and Bump (1964) in Washington, USA. According to Layard (1854), the female lays olive-green clutch of 9-16 eggs, pointed at one end and robust at the other. This large rate of egg production is compensated by a high rate of loss of

eggs. When incubating birds leave the nests, eggs are not covered and predators damage most of them. A late brood is raised as hen will lay eggs again if eggs are lost.

Typically 6-9 eggs per clutch were reported by Finn (1911) in Calcutta (India), and by Bump and Bump (1964) and del Hoyo *et al* (1994) in North America. Hussain *et al.,* (2012) reported 6-8 eggs / clutch in Pothwar area of Pakistan, where eggs were oval in shape and pale brown in color. The eggs are broad oval and sometimes pointed in shape. Eight to twelve eggs of pale buff are laid on consecutive days or at rather longer interval. Eggs are covered with dried grass and other material, till clutch completes. If first brood is destroyed, female may lay a second brood with smaller size (Romanoff, 1949). Complete clutches are removed to induce females to lay additional clutches Johnsgard, (1988). Both parents attend the young chicks after hatching (Roberts, 1991).

2.4. THREATS

Advancement in Science made more effective farming practices; use of fertilizers, pesticides, herbicides and advance machinery. The problem is severe due to large history of agriculture expansion in Europe (BirdLife, 2004; Bro *et al.*, 2001). All around the world, same situation has caused the problem for farmland birds, so position of grey partridge is not a particular example (Panek, 1997).

Population of grey partridge (*Perdix perdix*) has declined by 7% per year in Europe, but has seen about 79% overall population decline in all European countries over the last 50 years (PECBMS, 2007). Some countries have relatively stable

populations while others have seen major declines. There are countries having deficient data; for example there is lack of data or too little information available from Eastern Europe and Russia (PECBMS, 2007). Heavy use of pesticides that is associated with intensification of agriculture may affect the populations of grey partridge in some areas of Europe (del Hoyo *et al*., 1994). One can see the obvious influence on partridge populations that pesticides are having by a study conducted by the Game Conservancy Trust, who explained that before the introduction of herbicides, grey partridge (*Perdix perdix*) chick survival rate averaged 49%, but once pesticides use became widespread their survival rate reduced to 32% (Aesbischer and Potts, 1995). Bro *et al*., (2001) stated that predation is a major factor for partridge mortality, especially in areas where there is limited predation regulation during breeding season, especially in spring and summer. Regarding predation, availability of cover is a key factor for their survival as rate of predation are normally high around the year (Buner *et al*., 2005).

Farm vehicles also cause disturbance to grey partridge (*Perdix perdix*); movement and noise could cause birds to evacuate, deteriorate in health, or perhaps even death. In Europe, with grey partridge being one of the flagship species for farmland wildlife conservation, farmland birds have accounted for some of the highest declines in farmland wildlife (Donald *et al.*, 2002; Donald *et al*., 2006; PECBMS, 2007). Farm machinery directly damage nests of grey partridge (Bro *et al.*, 2001; De Leo *et al*., 2004). Aebischer and Kavanagh (1997) concluded that decrease in quantity of preferred insect prey for chicks, increased predation and loss of nesting cover are

considered to be most important reasons for decline in grey partridge (*Perdix perdix*) population in Europe during 20th Century. Parasites and disease is not a remarkable cause for decline in partridge but has been accounted for noticed. There has been confirmation of transmission of diseases and parasites to wild partridges from pheasants and released individuals of partridges (De Leo *et al*., 2004). According to Islam (1999), local populations of grey francolin (*Francolinus pondicerianus*) may be depressed because of the fact that birds are hunted and trapped in its native ranges for sale in the market and as cage birds but overall population seems unaffected as this species is tolerant of human activity and has adaptation to human modification.

Chapter 3

MATERIALS AND METHODS

3.1. STUDY AREA

The study was conducted at Chumbi Surla Wildlife Sanctuary (CSWS) and Diljabba-Domeli Game Reserve (DDGR) located in Salt Range, Pakistan. The Salt Range is an east-west turning point of communication about 175 km long in the northern Punjab consisting of Khushab, Mianwali, Jhelum and Chakwal districts (King and Vincent, 1993). It extends between 32º41 - 32º56 N and 71º50 - 74ºE, elevation 250 m-1520 m and forms an impressive scarp. Sakesar top is the highest point in Salt Range with an elevation of 1524 m (Awan, 1998).

Major habitat type in the area is arid sub-tropical, semi-evergreen scrub forest (Roberts, 1991). Dominant plant species include; *Zizyphus nummularia, Acacia modesta, Dodonaea viscosa, Pistacia integerrima, Monotheca buxifolia, Capparis aphylla, Gymnosporia royleana, Tecoma undulata* and *Olea ferruginea* (Sheikh, 1993). Salt Range supports a diverse and sufficient spectrum of wildlife species including Punjab Urial (*Ovis vignei punjabiensis*), Chinkara (*Gazella bennetti*), Grey francolin (*Francolinus pondicerianus*), Black francolin (*Francolinus francolinus*), Chukar (*Alectoris chukar*) and See-see Partridge (*Ammoperdix griseogularis*) due to nature of topography and vegetation diversity (Awan, 1998). Carnivores include Indian Wolf (*Canis lapus*), Jungle Cat (*Felis chaus*), Asiatic jackal (*Canus aureus*), Red Fox (*Vulpus vulpus*), and Yellow throated Martin (*Martes flavigula*).

The climate of study area is continental type, sub-tropical and sub-humid. There are two rainy seasons: i) monsoon rains occurring from mid July to mid September and ii) winter rains from January to March. Most of the precipitation is received in July and August and average precipitation from last 30 years was 853 mm. January being the coldest and June the hottest month with mean monthly temperature range of 5.9 ºC to 38.4 ºC. Temperature often drops below zero degree usually in December and January (Awan, 1998).

Crop cultivation in major livelihood of the people of Salt Range. Land ownerships are small and production of crop depends on rainfall. Major crops are lentils, groundnut, grams and wheat. Rearing of cattles is also common (GOP, 2000b). This area contains a number of lakes namely, Kallar Kahar (100 ha), Uchali (800 ha), Jhalar (100 ha) and Khabbeki (283 ha). The main streams of the area are Drabi, Bunha, Sauj and Gambir (GOP, 2000a).

Overgrazing and extraction of firewood in the past have resulted in the loss and degradation of most natural forests. Demands of local people which include grazing of sheep, goats, cattle and camels; firewood for cooking and heating; timber for agriculture implements and building purposes are met from these forests. People have the rights to collect firewood (dead and dry), and graze their cattle. Grass cutting is also allowed, however, lopping is not allowed. Illegal felling and cutting of tree are common (Sheikh, 1987).

Chumbi Surla Wildlife Sanctuary is situated at 20 km south- west of Chakwal

Town at 32º 47 N & 67º 42 E and 460 m – 1050 m elevation (Figure 3.1). Total area of CSWS is 55,987 ha (Azam *et al*., 2008). The sanctuary contains different habitat types including; wetlands, torrents, farm lands and hills, due to which good diversity of wild animals exist here. Climate of CSWS is dry sub-tropical with cool winters and hot summers. Temperature ranges from 10°C to 41 °C and average annual rainfall is 500 mm (Chaudhry *et al*., 1997). During 2011-2013, average minimum temperature was 3.7°C and maximum 39°C, average rainfall was 5.7-104 mm and maximum relative humidity was 62% (Table 3.1-3.3). The sanctuary has mixture of sub-tropical semi-evergreen and tropical thorn forest with dominant species of *Olea ferruginea, Tamarix aphylla, Dodonea viscosa, Acacia modesta, Justicia adhatoda, Withania coagulans*, *Raptonida buxifolia* and *Ziziphus nummularia*. Kahoon, located in the southern part of the sanctuary area is a wide valley with extensive cultivation. See-see partridge, Grey partridge, Black partridge, Chukar partridge, House Sparrow and White-cheeked Bulbul are common bird species of CSWS. Major mammalian fauna includes; Punjab Urial, Wild Boar, Asiatic Jackal, Red Fox, Indian Wolf, Jungle Cat, Indian Pangolin, Yellow-throated Marten, Indian crested Porcupine, Desert Hare, Indian Grey Mongoose and Indian Civet (Azam *et al*., 2008; Anwar and Goursi, 2012).

Diljabba- Domeli Game Reserve is located in district Jhelum at 32° 54 N - 73° 09 E and 600 m elevation. Total area of the game reserve is 118,106 ha (Figure 3.2). Major wildlife species include; Punjab Urial, Grey partridge, Black partridge, Chukar partridge, Desert hare, Wild boar, Spiney tailed lizard, Indian Pangolin, White-cheeked bulbul etc. Dominent plant species are; *Salvadora alights, Acacia modesta, Prosopis*

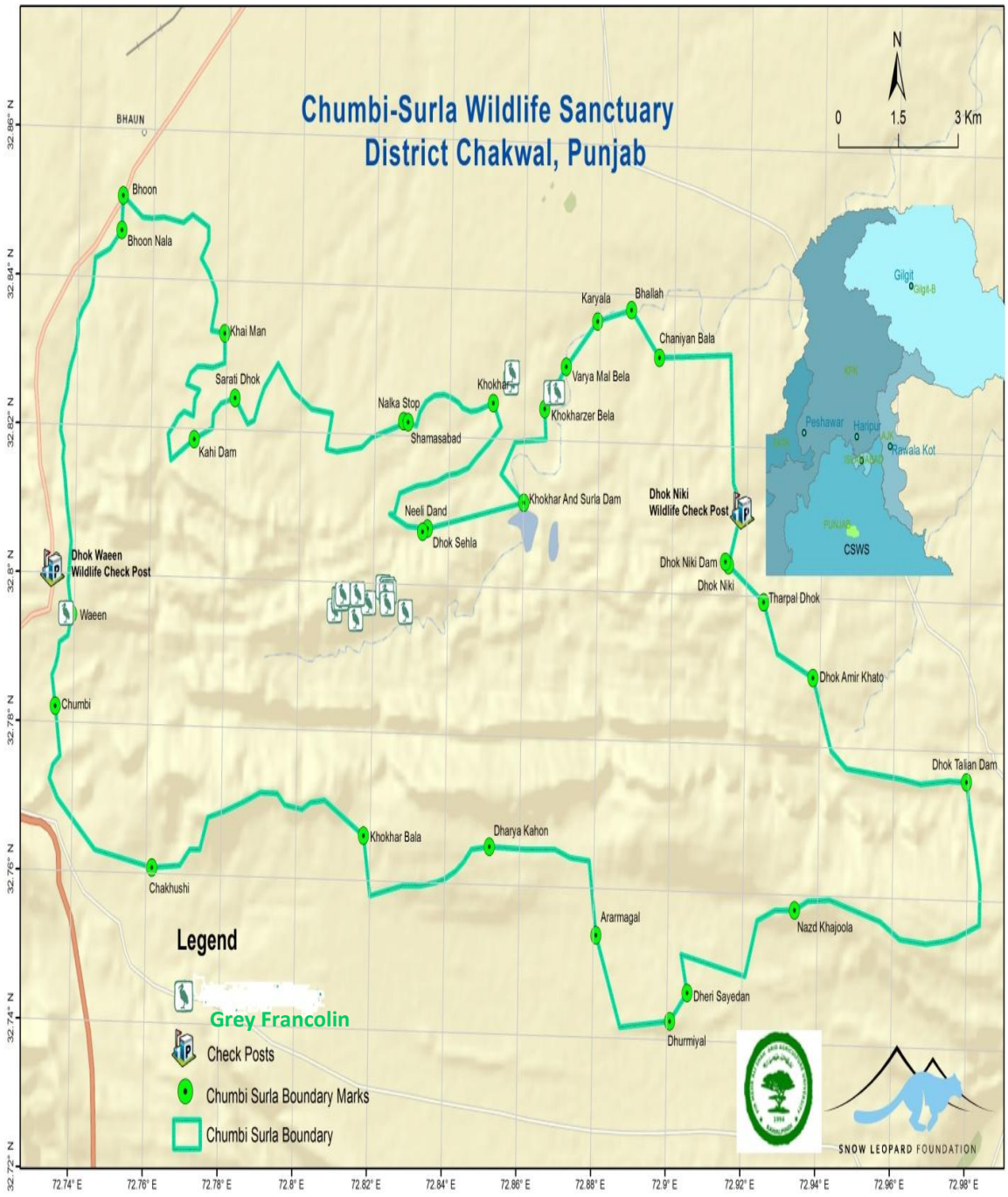

Figure 3.1: Map showing location of Chumbi Surla Wildlife Sanctuary and selected study sites for Grey Francolin.

Table 3.1: Mean temperatures (°C) recorded in Chumbi Surla Wildlife Sanctuary from 2011 to 2013.

Year	January		February		March		April		May		June		July		August		September		October		November		December	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
2011	5.4	20.5	8.1	20.0	15.4	30.1	19.3	35.8	21.8	38.5	23.4	39.4	24.8	35.7	24.2	32.5	22.1	33.1	18.6	31.8	10.7	26.8	4.7	19.9
2012	3.4	17.3	6.3	17.0	11.6	26.3	15.3	30.0	23.2	39.9	25.7	39.3	23.7	34.4	24.3	33.8	22.6	33.6	16.8	31.6	12.1	25.6	4.9	20.9
2013	2.3	15.7	2.9	16.6	8.7	25.6	15.3	30.0	23.0	38.2	25.0	38.5	24.0	35.0	23.5	31.9	22.0	34.0	15.8	30.5	12.0	24.5	4.0	18.0
	3.7	18	6.0	18.0	12.0	27.0	17.0	32.0	23.0	38.0	25.0	39.0	24.0	35.0	24.0	33.0	22.0	33.0	17.0	31.0	11.0	25.0	4.0	19.6

Source: Pakistan Metrological Department.

Table 3.2: Monthly rainfall (mm) data recorded in Chumbi Surla Wildlife Sanctuary from 2011 to 2013.

Year	January	Feburary	March	April	May	June	July	August	September	October	November	December
2011	10.2	54.8	15.2	9.2	76.4	57.0	214.1	123.8	19.3	17.5	0.0	14.0
2012	6.0	53.0	26.6	49.0	28.0	26.2	97.0	132.3	33.0	14.7	5.7	0.0
2013	17.4	19.8	0.0	42.7	***	***	***	***	***	***	***	0.0
	11	42.0	14.0	34.0	35.0	28.0	104.0	85.0	17.4	11.0	5.7	14.0

Table 3.3: Relative Humidity recorded in Chumbi Surla Wildlife Sanctuary from 2011 to 2013.

Year	January	Feburary	March	April	May	June	July	August	September	October	November	December
2011	55	61	51	37	34	42	65	80	70	53	57	52
2012	57	71	56	51	34	47	69	73	70	48	54	44
2013	56	54	38	51	***	***	***	***	***	***	***	***
	56	62	48	46	23	30	45	51	47	34	37	32

glandulosa, Zizyphus nummularia, *Olea ferruginea*, *Justicia adhatoda,* and *Calotrapis procera*. Shrubs are scattered and sparse where *Dodonea viscosa* is prominent and grasses like *Heteropogon contortus*, *Eleusine compressa* and *Cyonodon dactylon* are found (Awan, 1998; Anwar and Mehmood, 2010). In DDGR average minimum temperature recorded was 4°C and maximum 41°C, average rainfall range 5-225 mm and maximum relative humidity was 64% (Table 3.4-3.6).

3.2. STUDY DESIGN

3.2.1 Reconnaissance Survey of the Study Area

A reconnaissance survey was conducted to select the study sites for data collection within two study areas i.e. Chumbi Surla Wildlife Sanctuary and Diljabba-Domeli Game Reserve as representatives of Salt Range. Study sites were selected for data collection, on the basis of occurrence of grey francolin and accessibility of the area. Study area was divided into different habitat types as potential sites for the grey francolin.

3.3. HABITAT ANALYSIS TO DETERMINE THE PREFERRED HABITAT

Different types of potential habitats of grey francolin found in the study area were randomly selected for collecting data including; I) cultivated crop fields and associated natural vegetation on field boundaries, II) natural forest and associated grassland, III) open lands, and IV) wetlands and associated natural vegetation (Plate-3.1-3.8). To determine the preferred habitat of grey francolin, vegetative survey of selected habitat was conducted by using quadrate method as described by Schemnitz (1980).

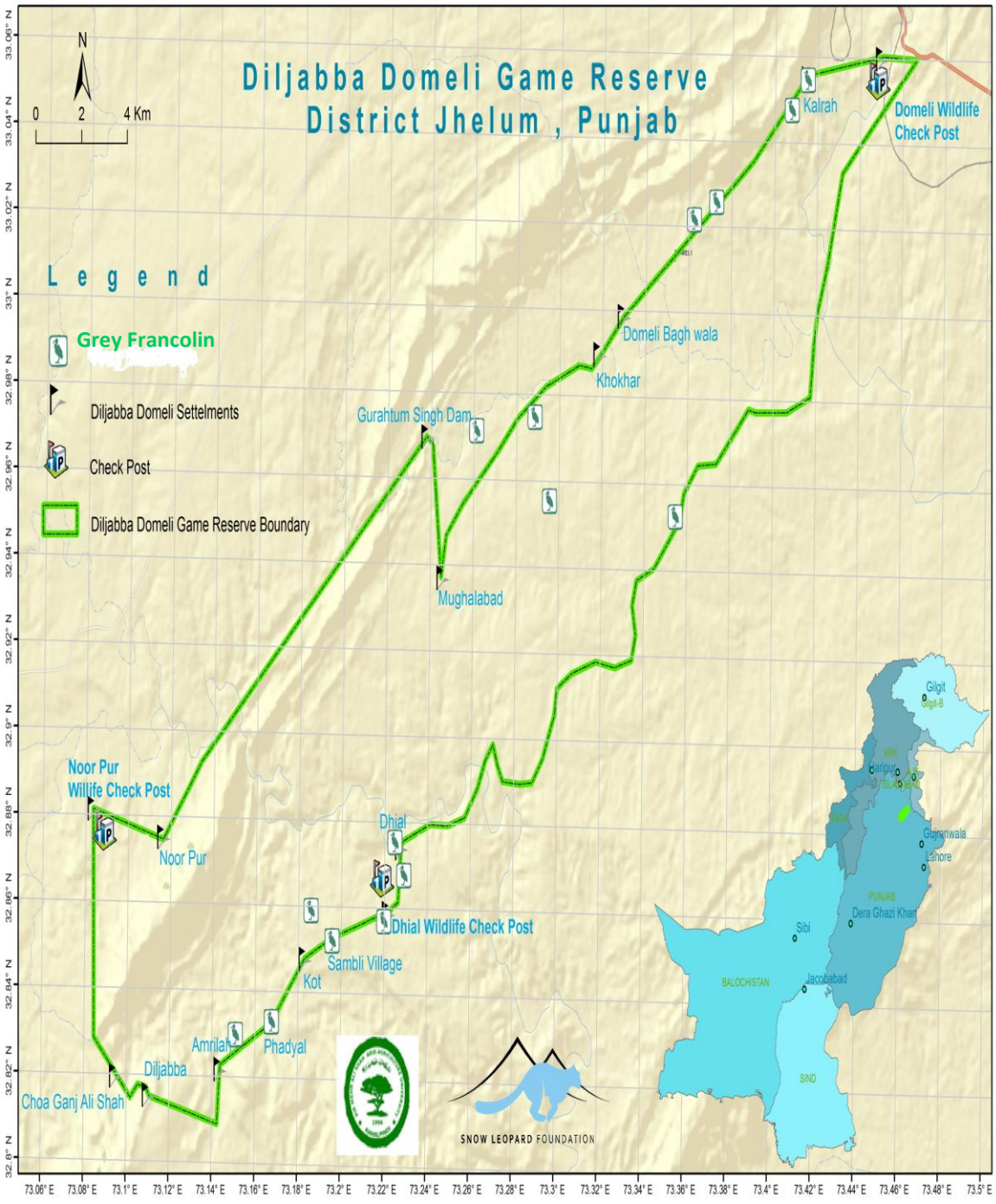

Figure 3.2: Map showing location of Diljabba Domeli Game Reserve and selected Study sites for Grey Francolin.

Table 3.4: Mean temperatures (°C) recorded in Diljabba Domeli Game Reserve from 2011 to 2013.

Year	January		February		March		April		May		June		July		August		September		October		November		December	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
2011	4.7	19.1	9.0	23.1	15.7	31.3	20.5	37.5	23.8	39.5	25.3	39.8	25.6	35.6	25.7	33.6	23.2	34.1	19.0	33.0	10.7	29.0	4.2	22.2
2012	4.3	18.2	8.6	20.5	13.3	28.9	17.5	32.3	24.6	40.5	26.2	39	25.8	35.1	25.7	34.5	23.6	34.7	17.5	33.2	12.1	28.9	4.4	23.9
2013	1.8	19.4	5.9	21	11.7	28.5	18.9	34	23	40.1	26.6	43.2	26.6	38.4	26.2	35.3	22.4	33.1	17.7	33.0	10.1	29.0	4.6	24.2
	4	19	8	21	13	29	19	35	24	40	26	41	26	36	25	34	23	34	18	33	11	29	4	23

Table 3.5: Rainfall (mm) recorded in Diljabba Domeli Game Reserve from 2011 to 2013.

Year	**January**	**Feburary**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
2011	3	75	10	13.2	51	76.7	259	161.9	57.3	23.4	0	14.6
2012	0	95.6	18	25.8	177	59	200.6	240.6	70.5	11.7	TR	0
2013	63.8	16.7	2	17.8	19.1	7.3	215	***	***	***	***	***
	22	62	10	19	82	48	225	134	42	12	0	5

Table 3.6: Relative Humidity recorded in Diljabba Domeli Game Reserve from 2011 to 2013.

Year	**January**	**Feburary**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
2011	65	54	50	28	33	36	64	75	64	60	55	59
2012	63	64	53	46	34	48	72	72	68	56	58	55
2013	58	50	41	43	28	26	57	***	***	***	***	***
	62	56	48	39	32	37	64	49	44	39	38	38

Ten quadrates each were taken randomly for trees, shrubs and herbs / grasses in each selected habitat type. Size of quadrates was 10 m x 10 m for trees, 4 m x 4 m for shrubs and 1 m x 1 m for herbs/grasses. Cover and frequency of plant species falling inside the quadtares were recorded and samples of unidentified plants were collected and got identified from Department of Botany, PMAS-Arid Agriculture University, Rawalpindi. The density, relative density, frequency, relative frequency, dominance, relative dominance and Importance Value Index (IVI) of recorded plant species were calculated for each selected habitat using the following formulae:

Density (D) = $\frac{\text{Total number of individuals of species}}{\text{Total area sampled}}$

Relative density (RD) = $\frac{\text{Total number of individual of species x100}}{\text{Total number of individuals of all species}}$

Frequency (F) = $\frac{\text{Number of quadrates in which species occurs}}{\text{Total number of quadrates}}$

Relative Frequency (RF) = $\frac{\text{Frequency value of species x 100}}{\text{Total frequency value of all species}}$

Dominance (D) = $\frac{\text{Cover of individuals of a species}}{\text{Total cover of all species}}$

Relative Dominance (RD) = $\frac{\text{Total basal area of individual species x100}}{\text{Total basal area of all species}}$

Importance Value Index (IVI) = IVI = RD + RF + RCo

Physical features of habitats such as elevation, slope, aspect, terrain and water availability were also noted. To record habitat features of Grey francolin in the study area, 80 quadrates (40 in CSWS and 40 in DDGR) in habitat use area (U) were laid out that contained Grey francolin or its signs; faecal pellets / droppings, footprints and feathers within a distance of 50-100 m from the quadrate (Aryal, 2009). Furthermore, other variables such as elevation, slope, aspect and water availability were also recorded from same habitat. The status of the area was changed to "habitat use" after any signs of grey francolin were found within the "habitat availability" area as whole "habitat availability" area does not contain signs of grey partridge. The preferred habitat was the one in which the occurrence of grey francolin or its signs recorded were maximum.

Ivelv's electivity index (IV) was used to analyze the habitat preference of grey francolin. Values of this index range from -1.0 to +1.0. The following formula was used:

IV = (U% - A %) / (U% + A %)

Where "U" represents "used" and "A" represents "availability". In this case, if for a habitat aspect (e.g. an elevation) IV > 0, this illustrate a preference by the francolin for that aspect, while IV < 0 indicates avoidance and IV = 0 indifference (Ivelv, 1964; Aryal, 2009).

3.4. POPULATION ESTIMATION IN SELECTED HABITATS

For population estimation of Grey francolin, direct sightings of the birds using

"Visual Encounter Method (VEM)" and call counts were used in four selected habitat types Five permanent transects of 0.5 km to 3km in length and 100 m (50 m on each side) in width were established, adjusting length and orientation of transect based on terrain of the site. Tansects were taken between 539 m (Khokhar Zer Dam) and 708 m (Dhok Sehla) in CSWS and between 395 m (Pathial Pahar) and 505m (Dhial) in DDGR. Transects were walked slowly by single observer in every month for four successive days, both in the morning (from 5 am to 8 am during summer and from 6 am to 10 am during winter) and the evening (from 5 pm to 8 pm during summer and from 2 pm to 5 pm during winter) to record direct sighting or calls of grey francolin depending on topography of land and nature of vegetation (Burnham *et al*., 1980). Population density for each site was calculated separately using by the sightings and call counts data. During breeding season calls were more prominent than direct sighting, so call counts method was also used for population estimation.

3.4.1. Estimation from Direct Sighting

Estimation of Grey francolin population was carried out by direct sighting of the birds along the transects. For every observation, sighting angle was recorded and perpendicular distance to the francolin was measured.

3.4.2. Estimation from Call Count Method

For estimation of Grey francolin population through call counts, the method of Javed and Kaul (2000) was used. Calls of Grey francolin were counted in each sample area early in the morning and evening. Grey francolin was assumed to have pairing for

mating during spring season. Each call was recorded individually by assuming that male grey francolin produced calls especially during breeding season. During observations utmost care was taken in data recording to avoid overlapping.

Both sighting and call count methods of population assessment were used to compare the effectiveness of methods under CSWS and DDGR conditions. Forty permanent line transect of 3 km length each were used. Transect line was walked with uniform speed for four successive days during different month of study period in the morning and evening hours. Numbers of grey francolin for each transect walk were recorded from sighting and calls. To work out the total number of calls and sightings for each month and for each time period (morning / evening), respective data for different transects were averaged / combined. Transect length being fixed, frequencies obtained from sighting and calls for different time periods and months were directly compared to observe the differences in population of grey francolin between different sites/habitats by ANOVA at 0.05 level of significance as used by Sokal and Rolf (2000).

For population analysis, DISTANCE version 6.0 was used (Buckland *et al*., 2009; Fewster *et al*., 2009; Thomas *et al*., 2010). The priority models (Key function/ sries expansion) used to arrive at density estimates included; Uniform - cosine, Half normal-Hermite polynomial and Hazard rate - Simple polynomial. Model selection was at the minimum of Akaike information criterion (AIC). As AIC provides a relative measure of fit. Distance also provides the ΔAIC values, with the AIC of best fitted model which are the values of AIC subtraction. Thus change in AIC is equal to zero

for the best model (Thomas *et al.*, 2010). The density estimation was made by pooled data of over all individuals encountered at transects.

3.5. BREEDING BIOLOGY OF GREY FRANCOLIN

Data on breeding biology of grey francolin was collected before onset of breeding season during March 2011 to September 2012. Direct field observations were taken at regular intervals, twice in a week to record data on onset of breeding season, nest size and structure, vegetation at nest site, clutch size, incubation period and hatching success. Nests were located by following individual francolin and/or based on their behavior with the help of wildlife watchers and local peoples. Approved methods were used to minimize the disturbance to the habitat and birds, and nest predation due to observer was avoided (Martin and Geupel, 1993). After locating an active nest (nest with a female, eggs, or fresh droppings was only considered active), it was marked by GPS and allotted a specific number. Marked nests were visited regularly 2-3 times in a week during early morning and late evening hours after short intervals from egg laying till hatching when nest was visited on daily basis.

I recorded dates of first and last egg laid, clutch size, date of hatching, number of of hatched egg, number of fledgling, shape, color and surface texture of eggs, length , width and volume of the eggs by using the formula, V= L x W (L= length, W= width of the egg), nest location, plant species at nesting site and general appearance or structure of the nest including inner and external diameter. Nest material was noted right away after predation or young fledge out successfully from the nest. Utmost care was taken during nest and egg measurements to ensure not to touch eggs with hand

and not disturb the nest (Soler *et al*. 1998). Bushnell 7x35mm binocular was used to locate and take observation on grey partridge, Sony DSC-HX 10V digital camera to take photographs of nests, eggs and francolin, Garmin etrex 10 GPS to take geo reference of grey francolin, Electronic LCD digital vernier caliper to measure eggs (Plate 3.9) and a digital scale (SF-820) having range of 0.1 mg to 300 g was used to weigh the eggs (Plate 3.10).

Prior to the analysis, normality of the data was checked using the Shapiro Wilk test (Shapiro and Wilk, 1965). As data distribution was not normal, a logarithm transformation, log (x+1), was used. One way Analysis of Variance (ANOVA; Clark, 2007) was used by software R 3.0.1 to test whether there were significant differences in the following features: 1) outer diameter of the nest; 2) inner diameter of the nest; 3) egg weight; 4) egg length; 5) egg width; 6) egg laying period; 7) clutch size; 8) incubation period; 9) hatching success and 10) fledging success, between forest and cultivated habitats. For categorical measurements of nest and egg, a contingency table was calculated using the software Past 3.0 (Hammer *et al*., 2001).

3.6. IDENTIFICATION OF FACTORS AFFECTING GREY FRANCOLIN HABITAT AND POPULATION

This study was based on questionnaire survey. To collect information about threats affecting grey francolin's population and its habitat in CSWS and DDGR, Primary data sources were the field observations, formal and informal interviews with the Wildlife staff, local people hunters and focus group discussions. Questionnaires were given to the literate people to fill the information and illiterate people were

interviewed. The surveys were conducted both in CSWS and DDGR. In total 100 questionnaires were filled from CSWS and DDGR, during which people of different age groups were divided into the categories; 15-25, 25-35, 35-45, 45-55, 55-65 and 65-75 years, having different occupations. Questionnaire consisted of two parts, first part designed to collect information about age and occupation of respondents living within and outside CSWS and DDGR. Second part was about population trend, major threats, hunting methods, trade life stage and predator of the grey francolin in the study area (Annexure 3.1). Conservation measures were suggested on the basis of results obtained.

Data was statistically analyzed using SPSS 16 software to test the hypothesis that all threats e.g., hunting, trade, habitat degradation, predation, livestock pressure, agriculture, fuel wood collection, land clearing and stone crushing, contributed equally or not. Chi square test was used (Random ORG, 1998), in which null hypothesis was that population of Grey francolin is affected equally by different threats in the study areas (CSWS and DDGR), while alternative hypothesis was that population of grey francolin is not affected equally by different threats. Level of significance was 0.05.

Chapter 4

RESULTS AND DISCUSSION

4.1 HABITAT STUDY OF GREY FRANCOLIN

4.1.1 Habitats in Chumbi Surla Wildlife Sanctuary

Four habitat types selected for this study included; Habitat I- cultivated crop fields and associated natural vegetation on field boundaries; habitat II- natural forest and associated grassland; habitat III - open land; and habitat IV- wetlands and associated natural vegetation. In total, thirty eight plants species were recorded from CSWS; among those seven were trees, five shrubs, fifteen herbs, nine grasses and two cultivated crops.

In Habitat-I, tree species were *Acacia modesta* (IVI=3.39), *Acacia nilotica* (IVI = 2.46), and *Ziziphus mortiana* (IVI = 2.46). Dominant shrubs were *Gymnosporia royleana* (IVI= 5.12), *Zizyphus jujuba* (IVI= 8.91), and herbs were *Cynoglosum lanceolatum* (IVI= 5.31), *Astragallus spinosus* (IVI= 4.87), *Asphodules tenuifolim* (IVI= 21.27), *Euphorbia granulata* (IVI= 3.49), *Boerhavia procumbens* (IVI= 4.21), *Achyranthes bidentata* (IVI= 5.45), *Carthamus oxyacantha* (IVI= 19.43), *Pergularia tomentosa* (IVI= 4.02), *Tribulus terrestris* (IVI= 4.4), *Chenopodium album* (IVI= 5), *Parthinium hysterophrus* (IVI= 6.69), *Solanum surattense* (IVI= 5.33), *Oxalis corniculata* (IVI=8.3), *Sonchus arvenses* (IVI=7.14) and *Sonchus asper* (IVI=10.29). Dominant grasses were *Cynodon dactylon* (IVI= 21.64), *Heteropogon contortus* (IVI= 48.84), *Polypogan monspeliensis* (IVI= 25.52), *Poa annua* (IVI= 7.37), *Saccharum*

bengalense (IVI= 6.65), *Desmostachya bipinnata* (IVI= 26.31) and *Eulaliopsis binata* (IVI= 2.43). Major crops of the habitat were *Eruca sativa* (IVI= 14.21) and *Arachis hypogaea* (IVI= 9.06) (Table 4.1). Elevation recorded for this habitat was 705 m to 717m with 25 º to 45 º slope and aspect was between open to close. There was no availability of permanent water source.

In Habitat-II, *Acacia modesta* (IVI= 46.66) and *Capparis decidua* (IVI= 19.54) were the only tree species while dominant shrubs included; *Gymnosporia royleana* (IVI= 17.99), *Ziziphus jujuba* (IVI= 10.11) and *Cappris spinosa* (IVI= 5.85). Only herb was *Sonchus arvenses* (IVI =4.44) and dominant grasses were *Cynodon dactylon* (IVI= 40.26), *Heteropogon contortus* (IVI= 34.82), *Desmostachya bipinnata* (IVI= 68.67), *Polypogan monspeliensis* (IVI= 13.74) and *Saccharum bengalense* (IVI= 37.77) (Table 4.2). Elevation ranged from 697m to 704m with slope of 20 º to 45 º and aspect was laid between open and close, having permanent source of water.

In Habitat-III, *Acacia modesta* (IVI= 46.55), *Acacia nilotica* (IVI= 3.67), *Olea ferruginea* (IVI= 19.69) *Ziziphus numularia* (IVI = 9.46) and *Capparis decidua (*IVI =17.18) were major tree. Dominant shrubs included; *Gymnosporia royleana* (IVI=13.18), *Ziziphus jujuba* (IVI= 15.17), *Adhatoda zeylanica* (IVI= 22.5), *Dodonea* viscosa (IVI= 19.86) and *Capparis spinosa* (IVI= 5.27). Herbs was *Boerhavia procumbens* (IVI = 3.72) *and Cynodon dactylon* (IVI = 16.14), *Heteropogon contortus* (IVI = 124.62) were dominant grasses (Table 4.3). Elevation of this habitat was between 652m-685m with slope of 15 º to 45 º and aspect record was open to close but not so dense with source of water.In Habitat-IV, the major tree species included *Olea*

Table 4.1: Plant species recorded from cultivated habitat of Chumbi Surla Wildlife Sanctuary.

Plant Species	**R.D**	**R.F**	**R.C**	**IVI**
Acacia modesta (T)	0.03	1.44	1.92	3.39
Ziziphus mauritiana(T)	0.06	1.44	0.96	2.46
Acacia nilotica(T)	0.06	1.44	0.96	2.46
Gymnosporia royleana (S)	0.31	2.89	1.92	5.12
Zizyphus jujuba(S)	0.73	4.34	3.84	8.91
Cynoglosum lanceolatum(H)	0.03	1.44	3.84	5.31
Astragallus spinosus(H)	0.06	2.89	1.92	4.87
Asphodules tenuifolim(H)	9.23	7.24	4.8	21.27
Euphorbia granulata(H)	0.13	1.44	1.92	3.49
Boerhavia procumbens(H)	0.27	2.89	0.96	4.21
Achyranthus bidentata(H)	0.17	1.44	3.84	5.45
Carthamus oxyacantha(H)	5.94	8.69	4.8	19.43
Pergularia tomentosa(H)	0.17	2.89	0.96	4.02
Tribulus terrestris(H)	1.04	1.44	1.92	4.4
Chenopodium album(H)	1.15	2.89	0.96	5.0
Parthinium hysterophorus(H)	0.9	2.89	2.88	6.69
Solanum surattense(H)	0.52	2.89	1.92	5.33
Oxalis corniculata(H)	0.59	5.79	1.92	8.3
Sonchus arvenses(H)	0.41	5.79	0.96	7.14
Sonchus asper(H)	2.09	7.24	0.96	10.29
Cynodon dactylon (G)	13.46	4.34	3.84	21.64
Heteropogon contortus (G)	37.77	4.34	6.73	48.84
Polypogan monspeliensis(G)	8.18	8.69	8.65	25.52
Poa annua(G)	2.09	1.44	3.84	7.37
Saccharum bengalense(G)	0.41	1.44	4.8	6.65
Desmostachya bipinnata (G)	13.32	4.34	8.65	26.31
Eulaliopsis binata(G)	0.03	1.44	0.96	2.43
Eruca sativa (C)	0.27	1.44	12.5	14.21
Arachis hypogaea (C)	0.41	2.89	5.76	9.06

Key: T= Tree, S=Shrub, H= Herb, G= Grass, C=Crop, RD = Relative Density, RF = Relative Frequency, RC= Relative Cover IVI = Importance Value Index (IVI = RD + RF + RD).

Tabl4.2: Plant species recorded from natural forest habitat of Chumbi Surla Wildlife Sanctuary.

Plant Species	**R.D**	**R.F**	**R.C**	**IVI**
Acacia modesta(T)	7.52	26.47	12.67	46.66
Capparis decidua(T)	2.03	14.7	2.81	19.54
Gymnosporia royleana(S)	0.6	11.76	5.63	17.99
Ziziphus jujuba(S)	1.42	5.88	2.81	10.11
Cappris spinosa(S)	0.1	2.94	2.81	5.85
Sonchus arvenses(H)	0.1	2.94	1.4	4.44
Cynodon dactylon (G)	15.95	8.82	15.49	40.26
Heteropogon contortus (G)	16.15	8.82	9.85	34.82
Desmostachya bipinnata (G)	40.14	8.82	19.71	68.67
Polypogan monspeliensis (G)	2.23	5.88	5.63	13.74
Saccharum bengalense(G)	13.71	2.94	21.12	37.77

Table 4.3: Plant species recorded from open land habitat of Chumbi Surla Wildlife Sanctuary.

Plant Species	**R.D**	**R.F**	**R.C**	**IVI**
Acacia modesta (T)	2.36	19.6	24.59	46.55
Ziziphus nummularia (T)	0.31	5.88	3.27	9.46
Olea ferruginea (T)	1.38	11.76	6.55	19.69
Acacia nilotica (T)	0.08	1.96	1.63	3.67
Gymnosporia royleana (S)	0.75	5.88	6.55	13.18
Ziziphus jujuba(S)	0.08	1.98	13.11	15.17
Adhatoda zeylanica (S)	1.91	15.68	4.91	22.5
Dodonea viscosa(S)	1.55	11.76	6.55	19.86
Capparis spinosa(S)	0.04	1.96	3.27	5.27
Boerhavia procumbens(H)	0.13	1.96	1.63	3.72
Cynodon dactylon (G)	10.91	1.96	3.27	16.14
Heteropogon contortus (G)	80.43	19.6	24.59	124.26

ferruginea (IVI= 4.81), *Acacia modesta* (IVI= 17.02), *Acacia nilotica* (IVI= 4.88) and *Butea monosperma* (IVI= 17.04). Major shrubs were *Gymnosporia royleana* (IVI = 11.67), *Ziziphus jujuba (*IVI = 32.93), *Cappris spinosa* (IVI = 7.06). Herbs were *Sonchus asper* (IVI = 4.88) and *Sonchus arvenses* (IVI= 9.38) *Cynodon dactylon* (IVI = 21.07), *Heteropogon contortus* (IVI = 52.73), *Desmostachya bipinnata* (IVI= 29.86), *Polypogan monspeliensis* (IVI= 8.4), *Saccharum bengalense* (IVI= 68.15), *Cenchrus ciliaris* (IVI= 4.88) and *Typha angustata* (IVI= 4.81) were dominant grasses (Table 4.4). Elevation record for this habitat was 533m to 561m with 20 º to 55 º slope and aspect was laid between open to close. There was availability of water source.

4.1.2 Habitats in Diljabba Domeli Game Reserve

Thirty four plant species were recorded from DDGR, including six trees, five shrubs, fourteen herbs, seven grasses and two cultivated crops.

In Habitat-I, *Acacia modesta* (IVI=17.52), *Acacia nilotica* (IVI = 3.97), were the major tree species with shrubs like *Gymnosporia royleana* (IVI= 2.62), Cappris*spinosa* (IVI= 4.34), *Adhatoda zeylanica* (IVI= 3.19).Dominant herbs were *Boerhavia procumbens* (IVI =2.45), *Carthamus oxyacantha* (IVI =20.5), *Achyranthus bidentata* (IVI =7.56), *Asphodules tenuifolim* (IVI =2.67), *Pergularia tomentosa* (IVI =3.45), *Tribulus terrestris* (IVI =3.79), *Sonchus arvenses* (IVI =4.29), *Chenopodium album* (IVI =11.63), *Oxalis corniculata* (IVI =10.7), *Parthinium hysterophorus* (IVI =9.77), *Solanum surattense* (IVI =5.41), *Sonchus asper* (IVI =3.95). *Cynodon dactylon* (IVI=46.62), *Heteropogon contortus* (IVI=23.52), *Desmostachya bipinnata*

*(*IVI=34.49), *Polypogan monspeliensis* (IVI= 34.58), *Saccharum bengalenses* (IVI=21.57) were dominant grass species and *Arachis hypogaea* (IVI= 4.15), *Brassica Compestris* (IVI=16.97) were crops (Table 4.5). In this habitat elevation record was 407m to 460m and slope was 15 º to 45 º, aspect was not so dense and water source was there.

In Habitat-II, *Acacia modesta* (IVI= 53.84), *Acacia nilotica* (IVI= 16.12), *Prosopis glandulosa* (IVI= 4.01), *Dalbergia sissoo* (IVI = 3.84) and *Capparis decidua* (IVI = 17.18) were the major tree species with *Gymnosporia royleana* (IVI = 24.55) *Ziziphus jujuba* (IVI= 10.51) as shrubs and *Heteropogon contortus* (IVI = 97.44), *Desmostachya bipinnata* (IVI = 24.17), *monspeliensis* (IVI = 31.61) and *Saccharum bengalense* (IVI = 16.49) as dominant grasses respectively (Table 4.6). Elevation of this habitat ranged from 505m to 523m with 25 º to 45 º slope and apectwas between open to close. There was availability of water source.

In Habitat-III, tree species included *Acacia modesta* (IVI= 16.27), *Acacia nilotica* (IVI= 3.44), *Ziziphus mortiana* (IVI= 11.06), *Prosopis glandulosa* (IVI= 5.37), and *Dalbergia sissoo* (IVI= 7.47). Major shrub was *Ziziphus jujuba* (IVI= 27.79) with herbs *Euphorbia granulate* (IVI=7.63), *Boerhavia procumbens* (IVI= 14.85) and grasses *Cynodon dactylon* (IVI = 16.29) *Heteropogon contortus* (IVI = 34.26) *Desmostachya bipinnata* (IVI = 60.45) *Cenchrus ciliaris* (IVI = 33.84) and *Saccharum bengalense* (IVI = 53.12) (Table 4.7). Elevation record for this habitat was 451m to 460m with 20 º to 45 º slope and aspect was close to in between. There was no availability of water source.

Table 4.4: Plant species recorded from wetland habitat of Chumbi Surla Wildlife Sanctuary.

Plant Species	**R.D**	**R.F**	**R.C**	**IVI**
Acacia modesta(T)	0.28	10	6.74	17.02
Olea ferruginea(T)	0.07	2.5	2.24	4.81
Butea monosperma(T)	0.56	7.5	8.98	17.04
Acacia nilotica(T)	0.14	2.5	2.24	4.88
Gymnosporia royleana(S)	0.21	5.0	6.47	11.67
Ziziphus jujuba(S)	1.7	20	11.23	32.93
Cappris spinosa(S)	0.07	2.5	4.49	7.06
Sonchus asper(H)	0.14	2.5	2.24	4.88
Sonchus arvenses(H)	0.14	2.5	6.74	9.38
Cynodon dactylon(G)	7.09	5	8.98	21.07
Heteropogon contortus (G)	29	12.5	11.23	52.73
Desmostachya bipinnata (G)	15.88	5.0	8.98	29.86
Polypogan monspeliensis(G)	1.41	2.5	4.49	8.4
Saccharum bengalense(G)	43.04	15	10.11	68.15
Cenchrus ciliaris(G)	0.14	2.5	2.24	4.88
Typha angustata(G)	0.07	2.5	2.24	4.81

Table 4.5: Plant species recorded from cultivated habitat of Diljabba Domeli Game Reserve.

Plant Species	**R.D**	**R.F**	**R.C**	**IVI**
Acacia modesta(T)	0.327	11.36	5.84	17.52
Acacia nilotica(T)	0.046	2.27	1.66	3.97
Gymnosporia royleana(S)	0.023	2.27	0.33	2.62
Cappris spinosa(S)	0.07	2.27	2.0	4.34
Adhatoda zeylanica (S)	0.09	2.27	0.83	3.19
Boerhavia procumbens(H)	0.023	2.27	0.16	2.45
Carthamus oxyacantha(H)	2.94	4.54	13.02	20.5
Achyranthus bidentata(H)	0.42	6.81	0.33	7.56
Asphodules tenuifolim(H)	0.07	2.27	0.33	2.67
Pergularia tomentosa(H)	0.023	2.27	1.16	3.45
Tribulus terrestris(H)	0.023	2.27	1.5	3.79
Sonchus arvenses(H)	0.023	2.27	2	4.29
Chenopodium album(H)	0.023	2.27	9.34	11.63
Oxalis corniculata(H)	0.49	4.54	5.67	10.7
Parthinium hysterophorus(H)	0.23	4.54	5	9.77
Solanum surattense(H)	0.21	4.54	0.66	5.41
Sonchus asper(H)	0.18	2.27	1.5	3.95
Cynodon dactylon (G)	30.02	9.09	7.51	46.62
Heteropogon contortus (G)	14.81	4.54	4.17	23.52
Desmostachya bipinnata (G)	17.43	4.54	12.52	34.49
Polypogan monspeliensis (G)	16.92	6.81	10.85	34.58
Saccharum bengalense(G)	6.78	2.27	12.52	21.57
Arachis hypogaea(C)	1.053	2.27	0.83	4.15
Brassica Compestris(C)	7.722	9.09	0.16	16.97

Table 4.6: Plant species recorded from natural forest habitat of Diljabba Domeli Game Reserve.

Plant Species	**R.D**	**R.F**	**R.C**	**IVI**
Acacia modesta(T)	6.56	29.41	17.87	53.84
Prosopis glandulosa(T)	0.138	2.94	1.004	4.07
Dalbergia sissoo(T)	0.138	2.94	0.803	3.87
Capparis decidua(T)	0.345	8.82	8.032	17.19
Acacia nilotica(T)	0.138	2.94	13.052	16.12
Gymnosporia royleana(S)	0.828	14.7	9.036	24.55
Ziziphus jujuba(S)	0.621	5.88	4.016	10.51
Heteropogon contortus (G)	59.8	20.58	17.068	97.44
Desmostachya bipinnata (G)	5.179	2.94	16.064	24.17
Polypogan monspeliensis (G)	20.71	5.88	5.02	31.61
Saccharum bengalense(G)	5.524	2.94	8.032	16.49

Table 4.7: Plant species recorded from open land habitat of Diljabba Domeli Game Reserve.

Plant Species	**R.D**	**R.F**	**R.C**	**IVI**
Acacia modesta(T)	1.19	6.06	9.02	16.27
Prosopis glandulosa(T)	0.09	3.03	2.25	5.37
Ziziphus mauritiana(T)	0.39	9.09	1.58	11.06
Dalbergia sissoo(T)	0.29	6.06	1.12	7.47
Acacia nilotica(T)	0.19	3.03	0.22	3.44
Ziziphus jujuba(S)	2.49	15.15	10.15	27.79
Euphorbia granulate(H)	0.09	3.03	4.51	7.63
Boerhavia procumbens(H)	0.89	6.06	7.9	14.85
Cynodon dactylon (G)	8.08	6.06	10.15	16.29
Heteropogon contortus (G)	11.27	6.06	16.93	34.26
Desmostachya bipinnata (G)	32.53	12.12	15.8	60.45
Cenchrus ciliaris(G)	6.28	15.15	12.41	33.84
Saccharum bengalense(G)	36.12	9.09	7.9	53.12

In Habitat-IV, *Acacia modesta* (IVI= 13.89), *Acacia nilotica* (IVI= 8.58), *Prosopis glandulosa* (IVI= 15.28) and *Dalbergia sissoo* (IVI = 26.44) were the tree species with *Ziziphus jujuba* (IVI= 19.79), *Adhatoda zeylanica* (IVI= 3.91) and *Calotropis procera* (IVI= *9.26*) shrubs. *Carthamus oxyacantha* (IVI= 6.14) and *Sorghum hellepense* (IVI= 42.38) were herbs and *Typha angustata* (IVI =12.39), *Cynodon dactylon* (IVI =36.62), *Desmostachya bipinnata* (IVI =15.64), *Cenchrus ciliaris* (IVI =7.49) and *Saccharum bengalense* (IVI =62.03) were grasses found here (Table 4.8). Elevation of this habitat was 363 m to 398 m with 15 º to 65 º degree slope and aspect was between open to close. There was availability of water source.

Dominant tree species in all selected habitats of CSWS were *Acacia modesta, Acacia nilotica, Dalbergia sissoo,* and *Olea ferruginea*, dominant shrubs were *Ziziphus jujuba, Gymnosporia royleana* and *Dodonea viscosa* and major grasses were *Heteropogon contortus, Desmostachya bipinnata, Saccharum bengalense* and *Cynodon dactylon* (Figure 4.1-4.4). Similarly, in DDGR, dominant tree species were *Acacia modesta, Acacia nilotica* and *Dalbergia sissoo.* Dominant shrubs were *Ziziphus jujuba* and *Gymnosporia royleana* and grasses were *Heteropogon contortus*, *Desmostachya bipinnata, Cynodon dactylon* and *Saccharum bengalense* (Figure 4.5-4.8).

Although these plant species were found in all habitats types in both study area (CSWS and DDGR), but they have different IVI value in each habitat; such as *Acacia modesta* has highest IVI value in both study areas among all tree species in three out of four selected habitats; cultivated, natural forest, and open land. *Butea monosperma* in

Table 4.8: Plant species recorded from wetland habitat of Diljabba Domeli Game Reserve.

Plant Species	**R.D**	**R.F**	**R.C**	**IVI**
Acacia modesta(T)	3.77	14.28	15.84	13.89
Prosopis glandulosa(T)	0.48	9.52	5.28	15.28
Dalbergia sissoo(T)	12.78	11.9	1.76	26.44
Acacia nilotica(T)	1.09	7.14	0.35	8.58
Ziziphus jujuba(S)	0.85	11.9	7.04	19.79
Adhatoda zeylanica (S)	0.48	2.38	1.05	3.91
Calotropis procera(S)	0.36	7.14	1.76	9.26
Carthamus oxyacantha(H)	0.24	2.38	3.52	6.14
Sorghum hellepense(H)	14.12	7.14	21.12	42.38
Typha angustata(G)	1.21	2.38	8.8	12.39
Cynodon dactylon (G)	13.64	7.14	15.84	36.62
Desmostachya bipinnata (G)	9.74	2.38	3.52	15.64
Cenchrus ciliaris(G)	0.97	4.76	1.76	7.49
Saccharum bengalense(G)	40.19	9.52	12.32	62.03

CSWS and *Dalbergia sissoo* in DDGR have higher IVI values as compared to other tree species present in the area. *Ziziphus jujuba* had high IVI value in cultivated and wetland habitats of CSWS and open land and wet land habitat of DDGR. Grass species; *Heteropogon contortus* have high IVI in cultivated and open land habitat in CSWS, and in natural forest habitat of DDGR, while IVI of *Desmostachya bipinnata* found highest in natural forest habitat of CSWS and open land habitat of DDGR. IVI of *Cynodon dactylon* was found high in cultivated habitat of DDGR. Plant species used for roosting by Grey francolin were also identified in the study area, which included *Acacia modesta, Acacia nilotica* and *Ziziphus jujuba* in CSWS and *Dilbergia sissoo, Acacia modesta* and *Ziziphus jujuba* in DDGR.

4.1.3 Habitat Preference in CSWS

In CSWS, Grey francolin showed high preference for the habitat having Ivelve's value of 0.26, elevation of 697 m to 704 m, with slope of 25 º to 55 º, open aspects (without dense vegetation cover) and where water was available. Second preference was given to aspect range not very open and close, having slope 20 º to 55 º, elevation between 533 m - 561 m, having Ivelve's value of 0.15. Habitat having an elevation of 652 m to 685 m, slope 15 º to 45 º and open aspect with water availability was also occasionally used by the grey francolin but not preferred. It showed no preference for the habitat with elevation range from 705 m to 717 m, slope of 25 º to 45 º having open aspect and source of water with Ivelve's value -0.05 (Table 4.9).

4.1.4 Habitat Preference in DDGR

In DDGR, high preference was shown by Grey francolin for habitat having

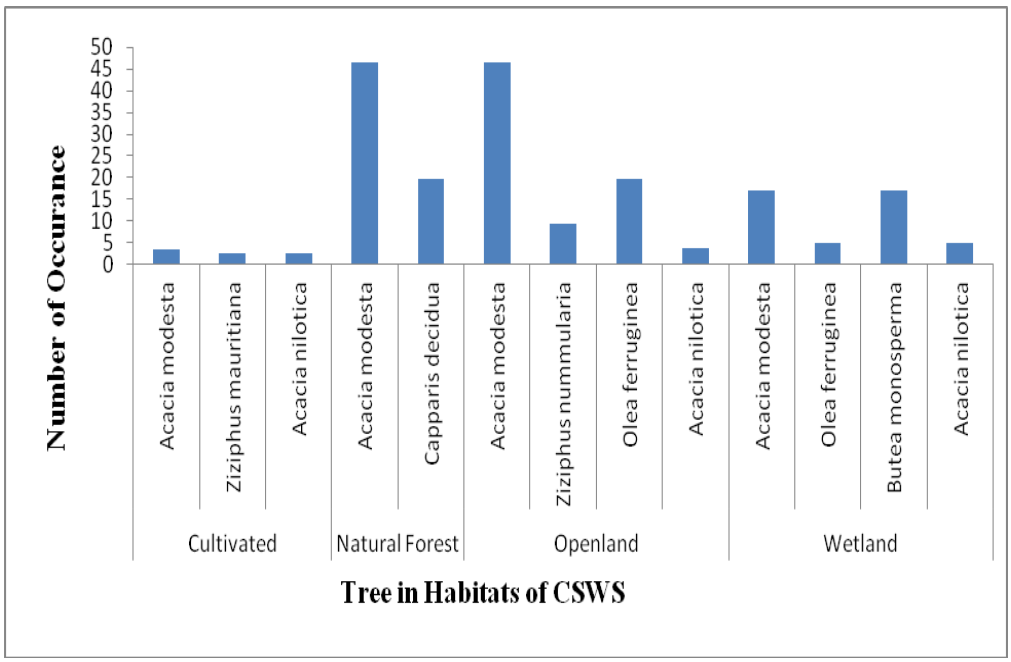

Figure 4.1: Graph showing tree species recorded in different habitat types in CSWS.

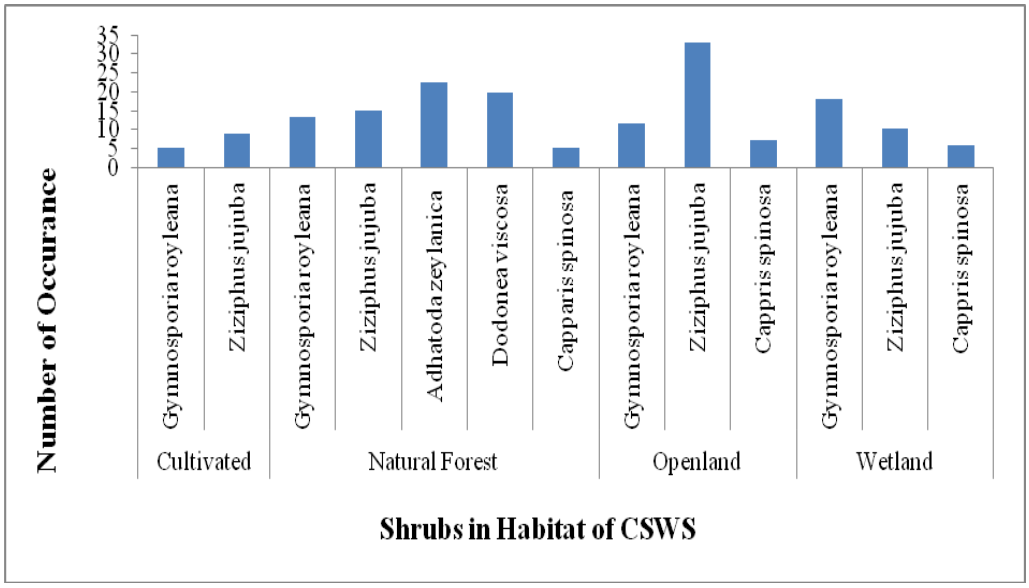

Figure 4.2: Graph showing shrub species recorded in different habitat types in CSWS.

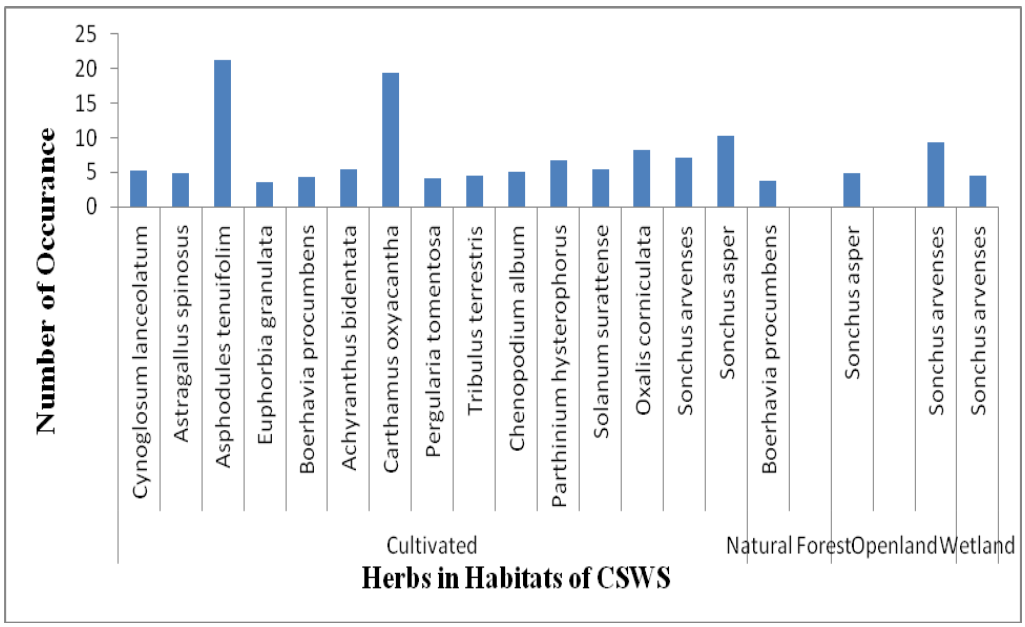

Figure 4.3: Graph showing herb species recorded in different habitat types in CSWS.

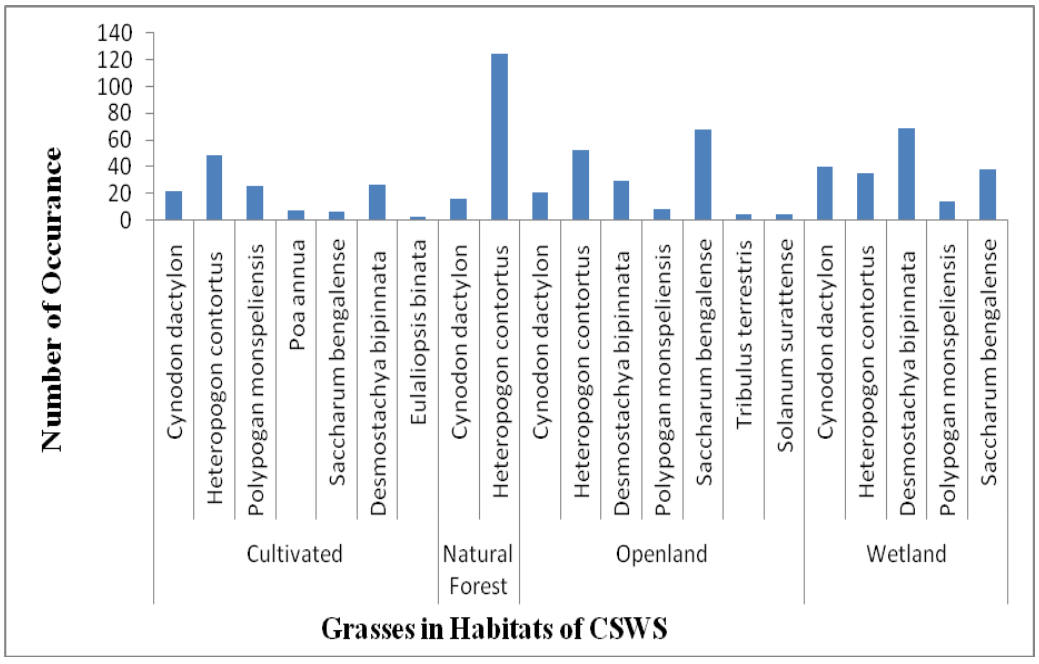

Figure 4.4: Graph showing grass species recorded in different habitat types in CSWS.

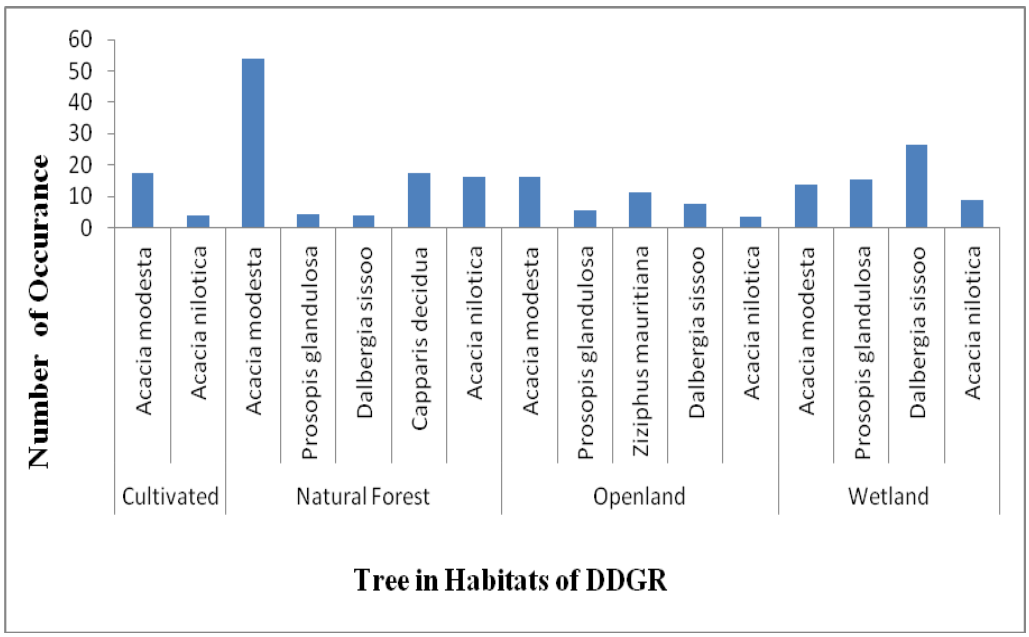

Figure 4.5: Graph showing tree species recorded in different habitat types in DDGR.

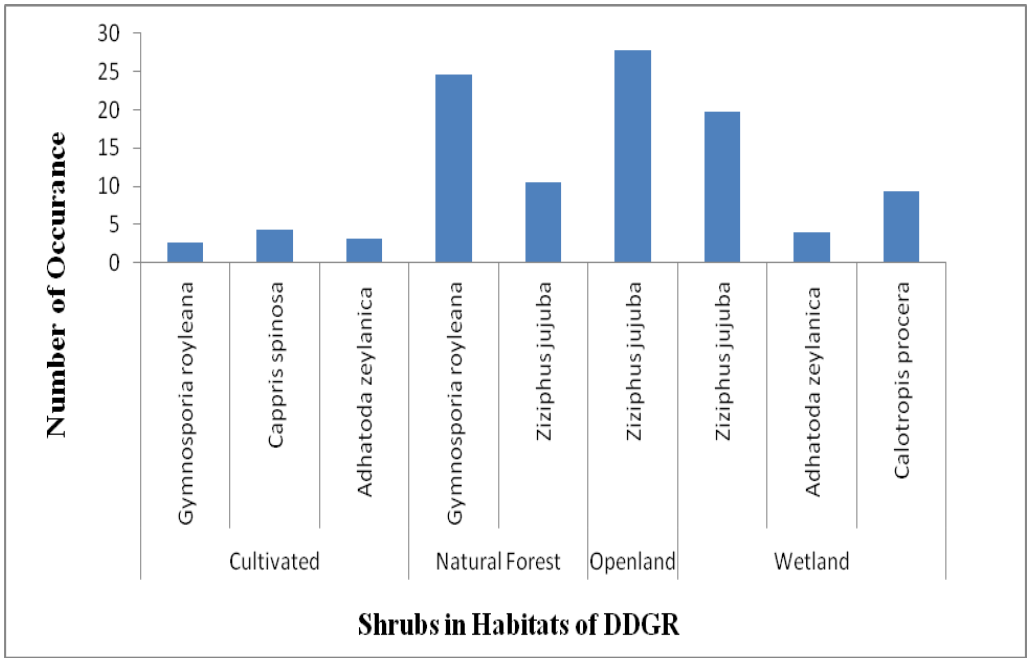

Figure 4.6: Graph showing shrub species recorded in different habitat types in DDGR.

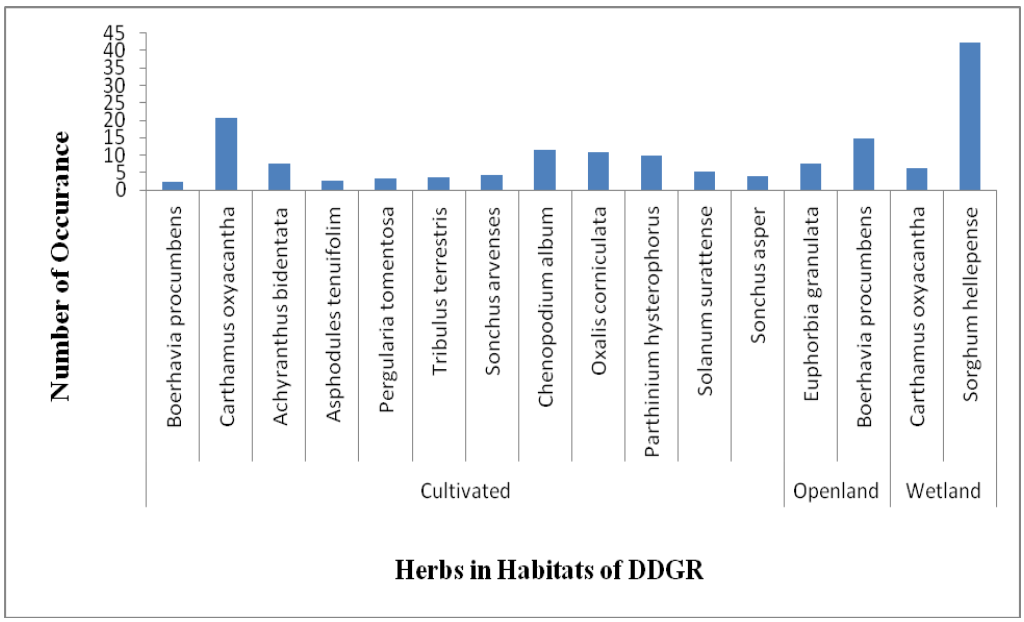

Figure 4.7: Graph showing herb species recorded in different habitat types in DDGR.

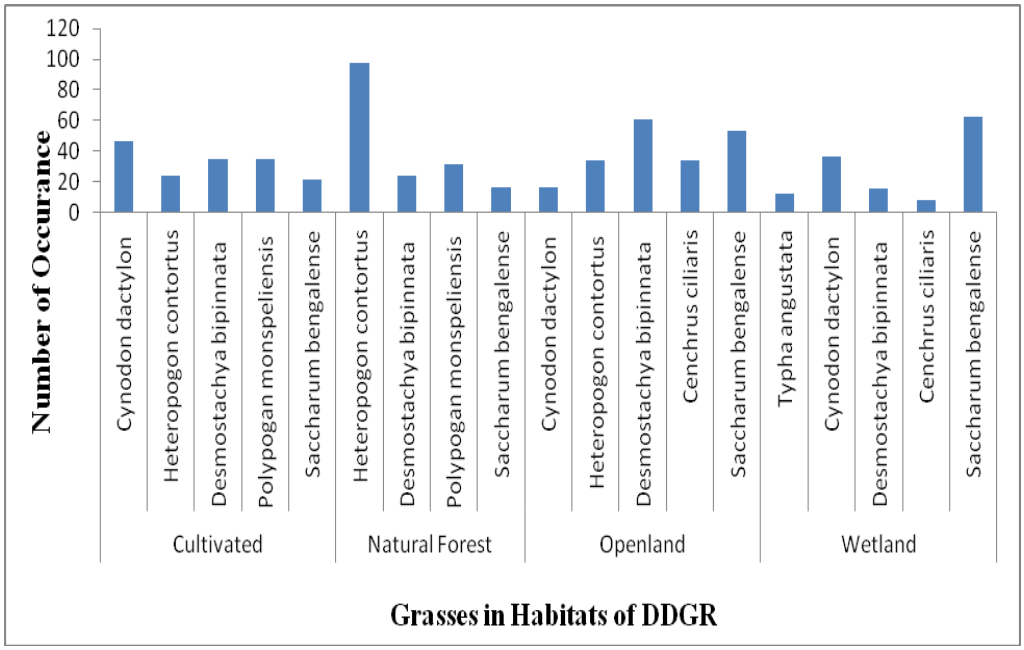

Figure 4.8: Graph showing grass species recorded in different habitat types in DDGR.

elevation from 505 m to 523 m with aspect that was not very close and slope of 25 º to 45 º with water availability having Ivelve's value 0.19. Second preference was given to the habitat with Ivelve's value 0.13 at elevation between 363m to 398m having slope of 15 º to 65 º and have both open and close aspects and water availability. Habitat with Ivelve's value 0 with an elevation of 407m to 460m, slope 15 º to 45 º and aspect range of close to not very dense , with water availability was randomly used by the species. While no preference was found for the habitat having an elevation range 451m to 460m and slope of 20 º to 45 º without water availability and aspect range from open to not very close with Ivelve's value of -0.08 (Table 4.10).

In CSWS, Habitat-II found as the most preferred habitat of Grey francolin which is natural forest having elevation from 697 m to 704 m (Figure 4.9), with slope of 25 º to 55 º (Figure 4.10), both open and close aspects and where water was available. In DDGR, high preference given by the Grey francolin to an elevation of 505 m to 523m (Figure 4.11), and aspect was not very close with slope of 25 º to 45 º (Figure 4.12), and water availability. In addition to have these variables, this habitat type had vegetation like *Acacia modesta, Acacia nilotica, Dalbergia sissoo,* and *Olea ferruginea*, which provides cover to the grey francolin for nest building and for roosting during night time. Highest IVI values of these tree species in the habitat with other variables as compared to other habitats caused the preference of this particular habitat by Grey francolin over other habitats in CSWS and DDGR.

The francolins require trees, shrubs, herbs and grasses, as these play important role in their survival by providing resting cover, shelter, nest location, and sites for

roosting during night time in any habitat. Hence, IVI value for tree and relative density, frequencies and cover of shrubs, herbs and grasses may demonstrate the population of francolins that may exists in a particular habitat.

The decreased vegetation cover is a source of increase in predation of the birds, and decreases the habitat protection to be warm and camouflage (Subramanian *et al*., 2002). Current study indicated that vegetation cover in CSWS and DDGR supports Grey francolin population and provides habitat for this species.

Presence of *Acacia modesta* and *Acacia nilotica* in three out of four selected habitats among 38 plant species in CSWS and 34 plant species in DDGR showed that Grey francolin prefers thorny vegetation in their habitat as compared to non thorny vegetation. These finding are supported by Khan (2010), who revealed that Grey francolin is mostly found in tropical thorn forest as compared to irrigated forest in Lal Suhanra National Park (LSNP), Pakistan. While presence of *Olea ferruginea* in habitats of grey francolin in CSWS and *Dalbergia sissoo* in DDGR, shrub of *Ziziphus jujuba* and grasses like *Heteropogon contortus*, *Desmostachya bipinata* and *Cynodon dactylon*, in both CSWS and DDGR habitats, indicates that these species are also important for grey francolin in its habitat selection, that may provide better cover for shelter and nesting and roosting sites.

In a study by Hussain *et al*., (2012) in agro-ecosystem of Pothwar Pleatue, Pakistan, scrub forest habitat was found to be preferred by Grey francolin, where dense cover of *Dalbergia sissoo* and *Desmstachia bipinnata* was available.

Table 4.9: Habitat variables used to calculate habitat preference of Grey Francolin in CSWS for Ivelv's electivity index (IV).

Habitat Type	Available Variables				Ivelve's Value	Used Variables
	Elevation (m)	Slope (°)	*Aspect	Water Availability		
I	705-717	25-45	4	0	-0.05	Avoid
II	533-561	20-55	1-4	1	0.15	Preferred
III	652-685	15-45	1-3	1	0	Random Use
IV	697-704	25-55	3-4	1	0.26	Preferred

*Aspect =1 (Open), 2(Close), 3(Not dense), 4(In-between).

Table 4.10: Habitat variables used to calculate the habitat preference of Grey Francolin in DDGR for Ivelv's electivity index (IV).

Habitat Type	Available Variables				Ivelve's Value	Used Variables
	Elevation (m)	Slope (°)	*Aspect	Water Availability		
I	407-460	15-45	3	1	0	Random Use
II	505-523	25-45	1-4	1	0.19	Preferred
III	451-460	20-45	2-3	0	-0.08	Avoid
IV	363-398	15-65	1-4	1	0.13	Preferred

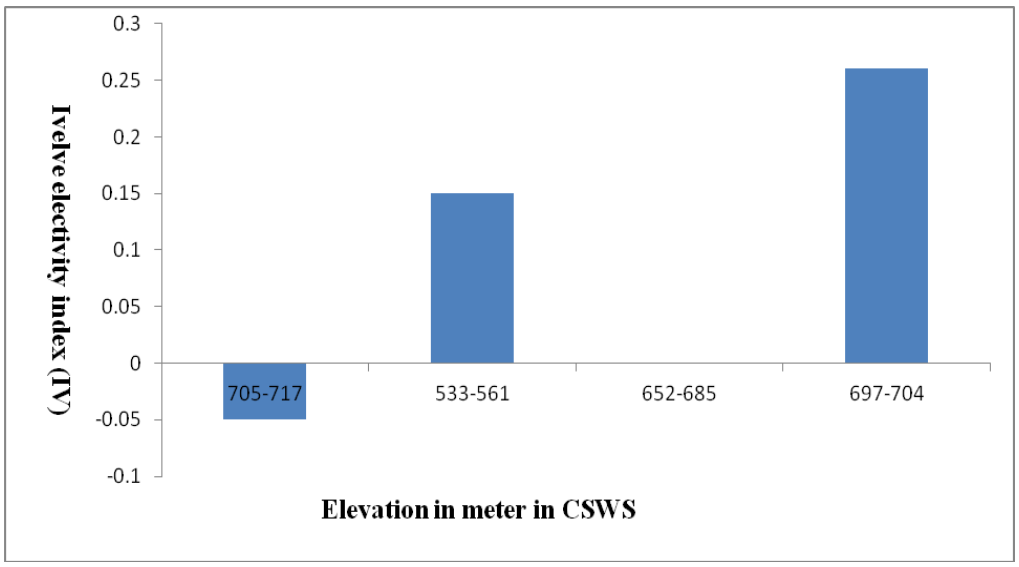

Figure 4.9: Elevation preference by Grey Francolin in CSWS.

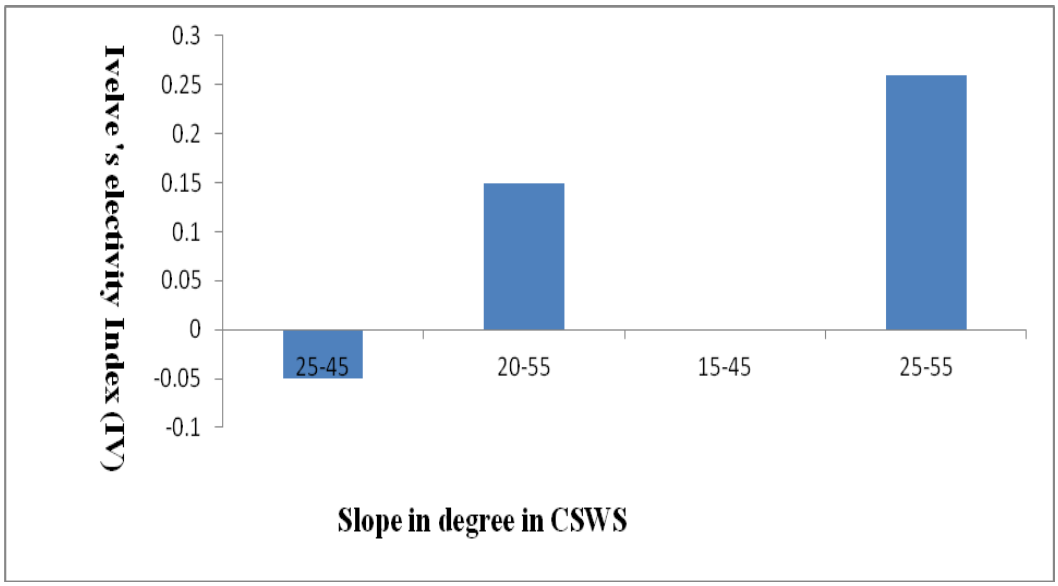

Figure 4.10: Slope preference by Grey Francolin in CSWS.

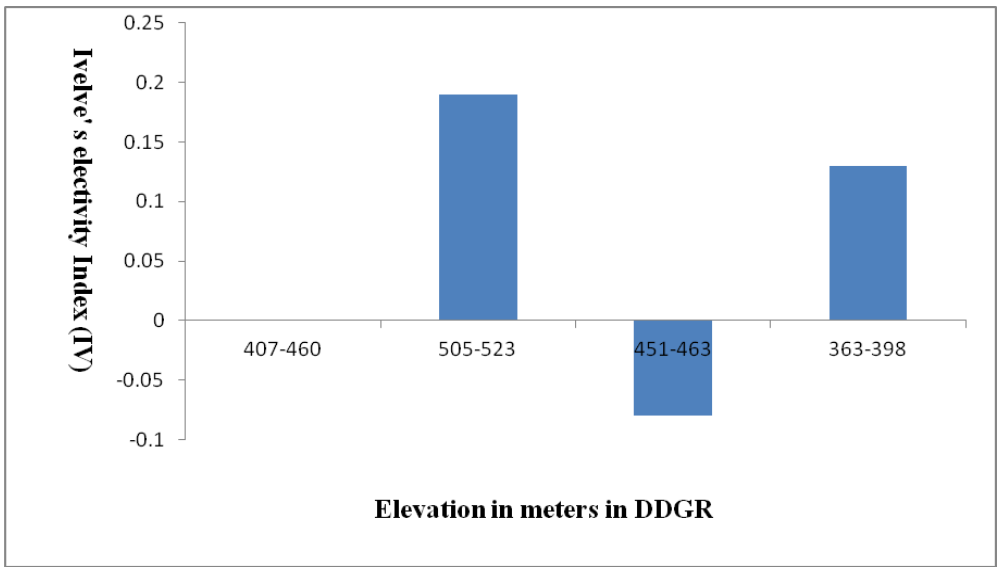

Figure 4.11: Elevation preference by Grey Francolin in DDGR.

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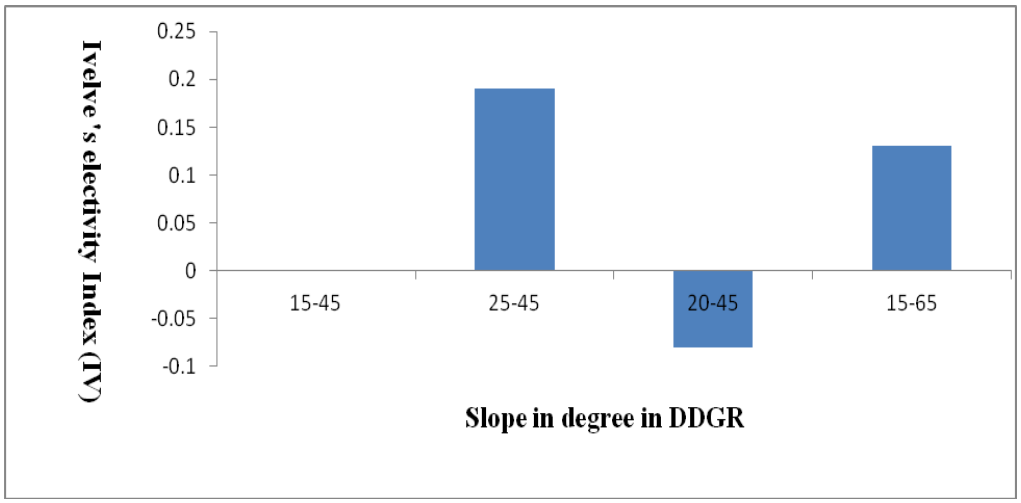

Figure 4.12: Slope preference by Grey Francolin in DDGR.

Habitat-II found a pure wild area with maximum values of IVI for trees (33.01) in CSWS and in DDGR (19.10) and IVI of shrubs (24.55) and (17.99), respectively. These findings are supported by Mahmood *et al*., (2010), who compared three different habitats to find out the most preferred habitat of Grey francolin in Lehri Nature Park, Punjab, Pakistan, wild habitat-II (natural forest) having high IVI value for trees (31.18) and high frequency of shrubs having (52.5) was the preferred habitat for species.

The results of the present study are also supported by other studies; Salek *et al.* (2004) proposed that high density of wild Grey partridge (*Perdix perdix*) were related with the presence of herbaceous land, unmanaged wild areas and farm land around it in Prague, the Czech Republic. Similarly, Liao *et al.* (2007), found that common Hill Partridge (*Arborophila torqueola)*, use areas that had wasteland with thick tree and shrub cover in Baiposhan Natural Reserve Sichuan, China. In Sri Lanka, Grey francolin mostly live in a habitat with low bushes and thorn scrub vegetation such as *Acacia eburnean* (Wijeyamohn *et al*., 2003). According to Ullah (1991), in Faisalabad Grey francolin lives in dry land. It was reported by Ali (2005) that in Rakh Sardaran Game Reserve, Hari Pur, Pakistan, grey francolin strongly preferred woodland and wooded ravines and avoided agricultural fields.

Tree species like *Acacia modesta*, *Acacia nilotica*, *Dalbergia sissoo* and shrub like *Ziziphus jujuba* were identified as main roosting tree for the grey francolin in the study area of CSWS and DDGR. According to Sangha (1987), in India, grey francolin roosts in groups in low thorny trees. At night it roosts on small trees like *Acacia*

nilotica and *Dalbergia sissoo*. Roberts (1991) found that grey francolin roosts on low trees and shrubs and sometimes on low branches, rarely found on the ground for roosting with sparse vegetation.

There is no such record of variables which are present in different habitat types and grey francolin shows preference or avoidance for that habitat in particular environment as recorded in this study like elevation, slope, aspect and availability of water source along with vegetation in an area. Only few studies address the importance of some attributes of habitat that are essential in the selection of a habitat by grey francolin such as Khan (2010) reported that grey francolin in desert condition of LSNP prefers places with thick shrub cover and soil moisture. Different type of vegetation plays an important role in sustaining of stable population of grey francolin in Salt Range (CSWS and DDGR). Although among all four selected habitats, there were small differences in frequencies and densities of shrubs, herbs and grasses, the major difference was found in IVI values for trees. Habitat-II found to have high elevation and aspect ranges with steep slope and having water with higher IVI for trees, seems to be the most important component for the Grey francolin to selects this habitat in the entire four habitats.

4.2 POPULATION ESTIMATION OF GREY FRANCOLIN

Area of Grey francolin habitat in scrub zone considered for distance sampling extended from Dhok Shela (32° 47.869" N, 72°48.659 "E) to Khokhar Zer Dam (32° 49.591 "N, 72°52 .023 "E), in CSWS (Table 4.11) and from Pathial Pahar (32° 50.131 N, 73° 16.053 E) to Kalewali (32° 51.544" N, 73° 12.651" E) in DDGR (Table 4.12).

Total 40 transects were laid in both areas and Grey francolin population were recorded both by direct sighting and calls counts.

4.2.1 Population Density in Chumbi Surla Wildlife Sanctuary (CSWS)

Estimated population density by direct sighting was 3.07 individual ha^{-1} (95% CI: 0.47 and 0.72) from Dhok Shela, 1.85 individual ha^{-1} (95% CI: 0.48and 0.82) from Subedarawali Mori, 3.23 individual ha^{-1} (95% CI: 0.45 and 0.71) from Bella, 3.19 individual ha^{-1} (95% CI: 0.45 and 0.65) from Khokhar Zer Dam (Table 4.13). By calls population estimation from both areas was 2.87 individual ha^{-1} (95% CI: 0.56 and 1.00) from Dhok shela, 1.59 individual ha^{-1} (95% CI: 0.51 and 0.88) from Subedarawali Mori, 2.17 individual ha^{-1} (95% CI: 0.50 and 0.96) from Bella, 1.88 individual ha^{-1} (95% CI: 0.44 and 0.69) from Khokhar Zer Dam (Table 4.14). Population density by sighting was the highest (3.23 individual ha^{-1}) at Bella while lowest at Subedarawali Mori (1.58 individual ha^{-1}). By call count method, it was the highest at Dhok sehla (2.87 individual ha^{-1}) while lowest at (95% CI: 0.51 and 0.88) at Subedarawali Mori (1.59 individual ha^{-1}) in CSWS. Effective width of transect for sighting was 41.12 (Dhok Shela), 44.38 (Subedarawali Mori) 25.67 (Bella), and 24.69 (Khokhar Zer Dam), for calls effective width was 45.92 (Dhok Shela), 47 was at (Subedarawali Mori), 48.54 (Bella), and 33.54 (Khokhar Zer Dam) in CSWS.

4.2.2 Population Density in Diljabba Domeli Game Reserve (DDGR)

Population were recorded through sighting in DDGR; 2.09 individual ha^{-1}(95% CI: 0.50 and 0.90) from Pathial Pahar, from Nathoot 2.51 individual ha^{-1} (95% CI: 0.45 and 0.68), from Dhial 2.45 individual ha^{-1} (95% CI: 0.44 and 0.70) and from

Table 4.11: Selected study sites for Grey Francolin population estimation in Chumbi Surla Wildlife Sanctuary.

S. No.	Location	Habitat Type	Elevation	Coordinates	
1	Dhok Sehla	Natural Forest	697m	32° 47.869 N	72°48.659 E
2	SubedaraWali Mori	Cultivated Field	708m	32° 47.775 N	72° 48.582 E
3	Bella	Open land	539m	32° 49.595 N	72° 52.127 E
4	Khokhar Zer Dam	Wetland	687m	32° 49.591N	72°52 .023 E

Table 4.12: Selected study sites for Grey Francolin population estimation in Diljabba Domeli Game Reserve.

S. No.	Location	Habitat Type	Elevation	Coordinates	
1	Pathial Pahar	Natural Forest	395m	32° 50.131 N	73°16.053 E
2	Nathoot	Cultivated Field	463m	32° 51.761 N	73° 11.941 E
3	Dhial	Open land	505m	32° 49.883 N	73° 09.406 E
4	Kalewali	Wetland	460m	32° 51.544N	73°12 .651 E

Kalewali 2.47 individual ha^{-1} (95% CI: 0.45 and 0.68) (Table 4.15). By calls 1.99 individual ha^{-1} (95% CI: 0.50 and 0.90) from Pathial Pahar, from Nathoot 1.25 individual ha^{-1} (95% CI: 0.45 and 0.92), from Dhial 2.45 individual ha^{-1} (95% CI: 0.43 and 0.75) and from Kalewali 1.10 individual ha^{-1} (95% CI: 0.42 and 0.79) (Table 4.16). In DDGR by sighting population was highest from Kalewali 2.47 individual ha^{-1} and lowest at 2.09 individual ha^{-1} from Pathial Pahar, by calls highest from Dhial 2.45 individual ha^{-1} and lowest from Kalewali 1.10 individual ha^{-1} .

In DDGR, effective width of transect for sighting was 43.74 (Pathial Pahar), 25.13 (Nathoot), 25. 37 (Dhial), 25. 05 (Kalewali) and 43.74 (Pathial Pahar), and for calls was 45.69 (Nathoot), 34.35 (Dhial) and 35.0 (Kalewali). There was significant difference in population densities among different sites and habitat types in both study area of CSWS (ANOVA: $F = 6.59$; $df = 3$; $P = 0.008$) and DDGR (ANOVA: $F = 6.59$; $df = 3$; $P = 0.042$) (Table 4.17). The conventional distance sampling analysis engine was used which models possibility to detect as a distance function from transect line. Distance sampling (Buckland *et al*., 2001) is an addition in sampling of an area, in which estimation of the birds are made inside fixed range. The plots are large, confined belt (sampling line transects) or bands (sampling point transects). Simple sampling in a defined area supposed that in the sample area all of the present birds are counted without error just before the arrival of the observer. The expansion in distance sampling gives the chance that some of the birds are not counted present in the area.The detection probability of an animal decreases with increasing distance from transect line (Thomas *et al.*, 2010).

Table 4.13: Summary of candidate model used and model fit in line transect analysis of Grey Francolin by sighting in CSWS.

Name of Sites	Population Estimation Model	No. of Parameter	ΔAIC	AIC	ESW/EDR	D/Hac	95% confidence interval	
							Lower	Upper
Dhok Sehla	Uniform / cosine	1	0.00	289.58	41.12	3.074	1.282	7.371
	Half normal /hermite polynomial	1	0.53	291.11	41.43	3.051	1.271	7.328
	Hazard rate /simple polynomial	2	1.45	292.03	37.37	3.559	1.357	9.331
Subedara Wali Mori	Uniform / cosine	1	0.00	259.67	44.38	1.856	4.713	0.415
	Half normal /hermite polynomial	1	1.08	260.76	46.86	1.683	4.285	0.420
	Hazard rate /simple polynomial	2	2.58	260.26	43.35	2.017	6.580	0.626

Continue……

… Table 4.13 continued

Name of Sites	Population Estimation Model	No. of Parameter	ΔAIC	AIC	ESW/EDR	D/Hac	95% confidence interval	
							Lower	Upper
Bella	Uniform / cosine	1	0.00	221.54	25.67	3.231	1.550	6.736
	Half normal /hermite polynomial	1	0.47	222.01	26.29	3.173	1.496	6.731
	Hazard rate /simple polynomial	2	1.19	222.73	27.14	2.860	1.324	6.181
Khokhar Zer Dam	Uniform / cosine	1	0.00	211.89	24.69	3.199	1.376	7.433
	Half normal /hermite polynomial	1	0.77	212.66	24.78	3.228	1.370	7.605
	Hazard rate /simple polynomial	2	0.84	212.72	28.24	2.297	0.982	5.374

Table 4.14: Summary of candidate model used and model fit in line transect analysis of Grey Francolin by calls in CSWS.

Name of Sites	Population Estimation Model	No. of Parameter	ΔAIC	AIC	ESW/EDR	D/Hac	95% confidence interval	
							Lower	Upper
Dhok Sehla	Uniform / cosine	1	0.00	409.11	45.92	2.879	1.285	6.453
	Half normal /hermite polynomial	1	0.57	409.68	49.07	2.442	1.094	5.455
	Hazard rate /simple polynomial	2	2.23	411.34	47.29	2.686	1.130	6.383
Subedara wali Mori	Uniform / cosine	1	0.00	337.05	47.14	1.599	0.681	3.753
	Half normal /hermite polynomial	1	0.80	337.85	50.19	1.420	0.604	3.336
	Hazard rate /simple polynomial	2	2.48	339.53	47.46	1.635	0.576	4.645

Continue….

… Table 4.14 continued

Name of Sites	Population Estimation Model	No. of Parameter	ΔAIC	AIC	ESW/EDR	D/Hac	95% confidence interval	
							Lower	Upper
Bella	Uniform / cosine	1	0.00	262.25	48.54	2.179	1.913	5.202
	Half normal /hermite polynomial	1	0.26	262.51	50.78	1.939	1.812	4.631
	Hazard rate /simple polynomial	2	1.96	264.21	47.05	2.378	1.851	6.641
Khokhar Zer Dam	Uniform / cosine	1	0.00	183.02	33.54	1.885	0.884	4.017
	Half normal /hermite polynomial	1	0.67	183.70	34.76	1.830	0.830	4.036
	Hazard rate /simple polynomial	2	1.04	184.06	36.53	1.505	0.676	3.349

Table 4. 15: Summary of candidate model used and model fit in line transect analysis of Grey Francolin by sighting in DDGR.

Name of Sites	Population Estimation Model	No. of Parameter	ΔAIC	AIC	ESW/EDR	D/Hac	95% confidence interval	
							Lower	Upper
Pathial Pahar	Uniform / cosine	1	0.00	306.80	43.74	2.097	1.261	3.486
	Half normal /hermite polynomial	1	0.18	306.98	46.22	1.898	1.135	3.175
	Hazard rate /simple polynomial	2	1.31	308.12	48.07	1.598	0.933	2.735
Nathoot	Uniform / cosine	1	0.00	168.63	25.13	2.516	1.343	4.713
	Half normal /hermite polynomial	1	0.65	169.29	24.97	2.561	1.317	4.982
	Hazard rate /simple polynomial	2	1.16	169.79	26.05	2.186	1.098	4.354

Continue….

… Table 4.15 continued

Name of Sites	Population Estimation Model	No. of Parameter	ΔAIC	AIC	ESW/EDR	D/Hac	95% confidence interval	
							Lower	Upper
Dhial	Uniform / cosine	1	0.00	161.96	25.37	2.458	1.354	4.462
	Half normal /hermite polynomial	1	1.64	162.60	25.53	2.459	1.397	4.663
	Hazard rate /simple polynomial	2	1.28	163.24	26.70	2.088	1.072	4.068
Kalewali	Uniform / cosine	1	0.00	198.59	25.05	2.476	1.097	5.589
	Half normal /hermite polynomial	1	0.69	199.28	25.67	2.423	1.054	5.570
	Hazard rate /simple polynomial	2	0.70	199.29	29.17	1.781	0.783	4.051

Table 4.16: Summary of candidate model used and model fit in line transect analysis of Grey Francolin by calls in DDGR.

Name of Sites	Population Estimation Model	No. of Parameter	ΔAIC	AIC	ESW/EDR	D/Hac	95% confidence interval	
							Lower	Upper
Pathial Pahar	Uniform / cosine	1	0.00	306.80	43.74	1.997	0.953	4.182
	Half normal /hermite polynomial	1	0.18	306.98	46.22	1.808	0.861	3.796
	Hazard rate /simple polynomial	2	1.31	308.12	48.07	1.522	0.717	3.230
Nathoot	Uniform / cosine	1	0.00	194.06	45.69	1.619	0.681	3.850
	Half normal /hermite polynomial	1	0.20	194.27	47.61	1.486	0.623	3.548
	Hazard rate /simple polynomial	2	1.93	196.00	44.00	1.483	0.527	6.442

Continue…

… Table 4.16 continued

Name of Sites	Population Estimation Model	No. of Parameter	ΔAIC	AIC	ESW/EDR	D/Hac	95% confidence interval	
							Lower	Upper
Dhial	Uniform / cosine	1	0.00	168.44	34.35	1.259	0.492	3.225
	Half normal /hermite polynomial	1	0.51	168.95	36.43	1.177	0.450	2.079
	Hazard rate /simple polynomial	4	3.88	172.32	39.60	0.908	0.334	2.471
Kalewali	Uniform / cosine	1	0.00	161.32	35.00	1.101	0.442	2.743
	Half normal /hermite polynomial	1	0.38	161.70	37.76	1.006	0.393	2.571
	Hazard rate /simple polynomial	2	0.70	162.02	40.43	0.784	0.312	1.971

Table 4.17: ANOVA table showing difference in population density of Grey Francolin between study sites of CSWS and DDGR.

Study Site	ANOVA-Single Factor							
	Groups	Count	Sum	Average	df	P-value	F-critical	Level of Sig.
CSWS	Subedarawali Mori	2	252	126	3	0.008	6.59	0.05%
	Dhok Sehla	2	400	200				
	Bella	2	250	125				
	Khokhar Zer Dam	2	207	103.5				
DDGR	Pathial Pahar	2	180	90	3	0.042	6.59	
	Nathoot	2	248	124				
	Dhial	2	155	77.5				
	Kalewali	2	151	75.5				

The detection probabilities by sighting were 0.71 at Dhok sehla (Figure 4.13), 0.63 Subedarawali Mori (Figure 4.14), 0.57 at Bella (Figure 4.15), and 0.54 at Khokhar Zer Dam (Figure 4.16). Probability of detection by calls was 0.76 at Dhok sehla (Figure4.17), 0.67 at Subedarawali Mori (Figure 4.18), 0. 69 at Bella (Figure 4.19), 0.55 Khokhar Zer Dam (Figure 4.20). In DDGR detection probabilities by sighting were 0.67 at Pathial Pahar (Figure 4.21), 0.55 at Nathoot (Figure 4.22) 0.56 at Dhial (Figure 4.23) and 0.55 at Kalewali (Figure 4.24), while by calls were 0.67 at Pathial Pahar (Figure 4.25), 0.65 at Nathoot (Figure 4.26), 0.57 at Dhial (Figure 4.27) and 0.58 at Kalewali (Figure 4.28).

The data collected on the population distribution of Grey francolin revealed that this species was not evenly distributed in different sites of the study area which is evident from difference in its population density at different locations and habitats of both study areas. Highest population density recorded by sighting in CSWS was at Bella (3.23 individual ha-1) that was an open land with sparse vegetation in the middle of the area, which increased visibility of birds during daily activities and thick vegetation on its boundaries provides cover for them to live in open land habitat. Lowest population in CSWS was at Subedarawali Mori (1.58 individual ha^{-1}) that was cultivated cropland having different cropping pattern during year. In a study conducted in Lal Suhanra National Park (LSNP), Mian and Ghani (2007), reported very low densities of Grey francolin i.e. 0.83 and 0.60 individuals / km^2 in intensively protective desert tracts.

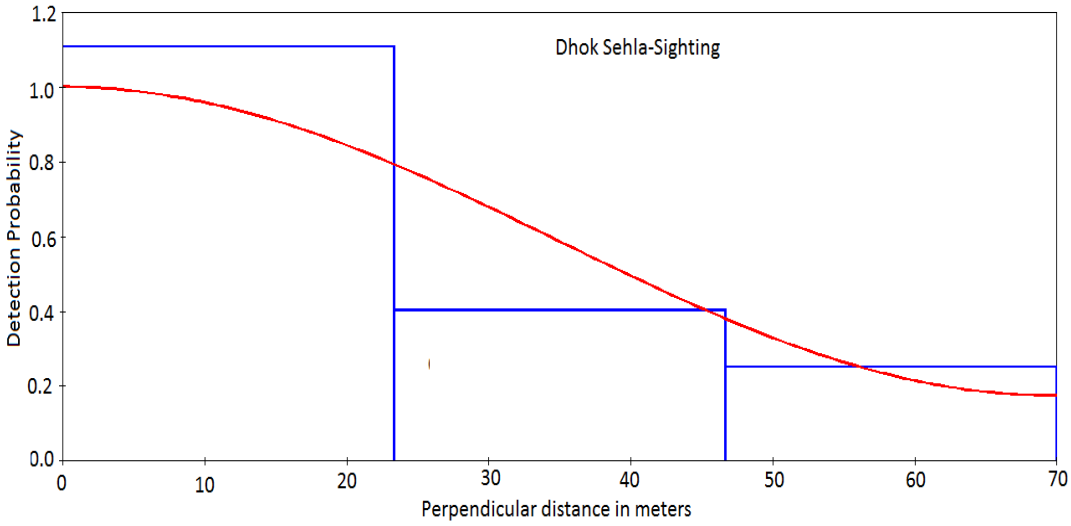

Figure 4.13 : Distance function curve for Grey Francolin sightings in natural forest habitat in Chumbi Surla Wildlife Sanctuary.

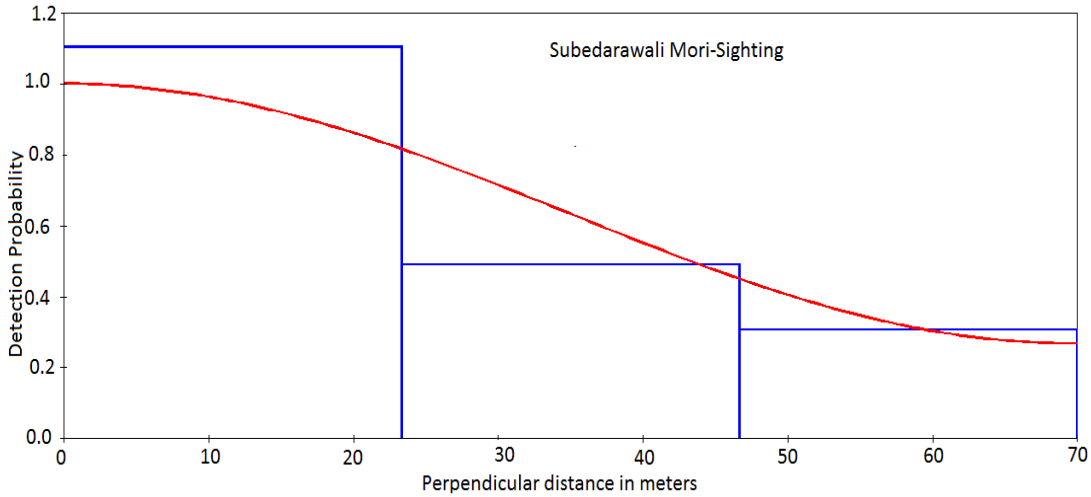

Figure 4.14 : Distance function curve for Grey Francolin sightings in cultivated habitat in Chumbi Surla Wildlife Sanctuary.

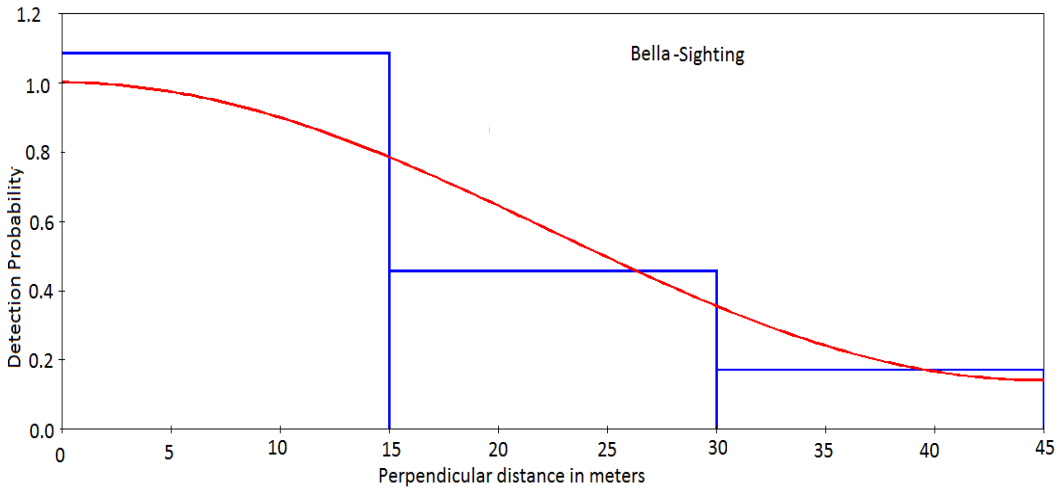

Figure 4.15 : Distance function curve for Grey Francolin sightings in openland habitat, Chumbi Surla Wildlife Sanctuary.

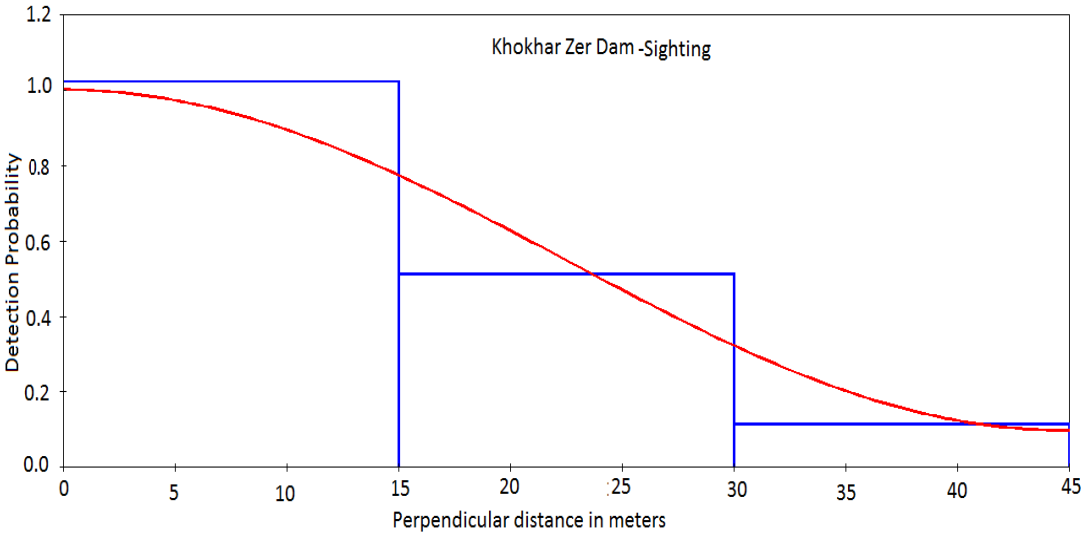

Figure 4.16: Distance function curve for Grey Francolin sightings in wetland habitat, Chumbi Surla Wildlife Sanctuary.

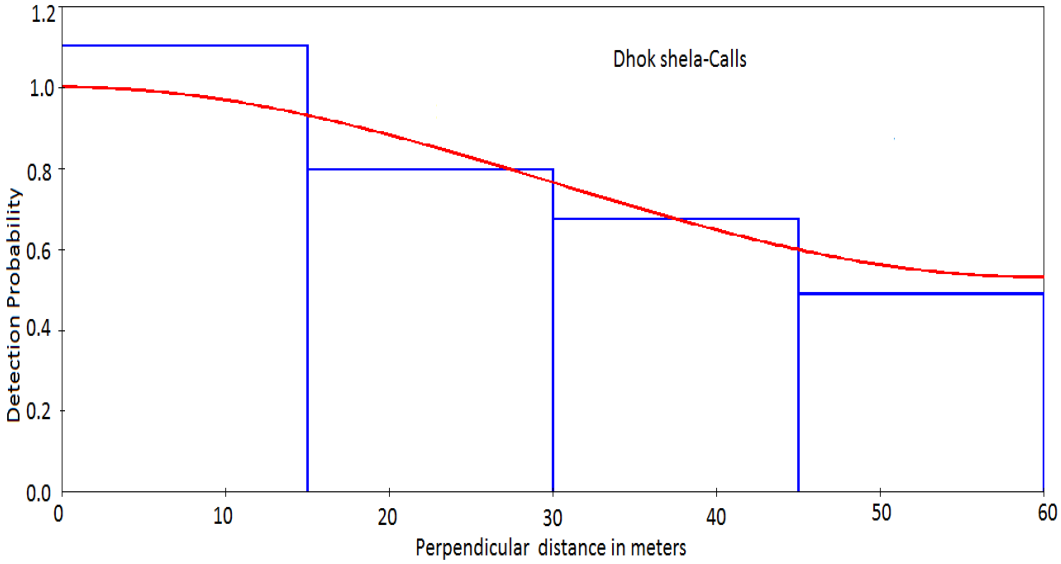

Figure 4.17 : Distance function curve for Grey Francolin Calls in natural forest habitat, Chumbi Surla Wildlife Sanctuary.

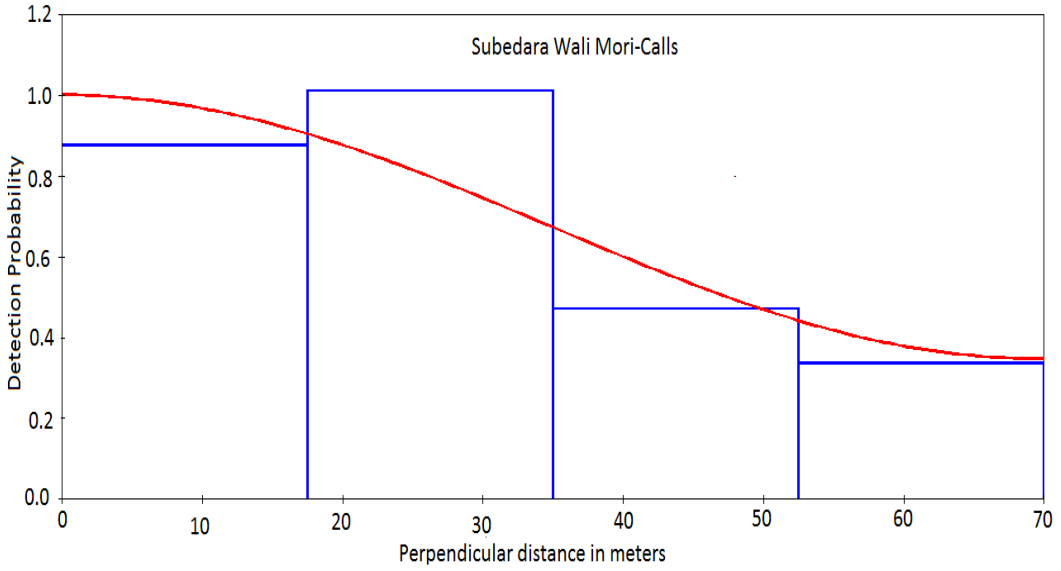

Figure 4.18 : Distance function curve for Grey Francolin Calls in cultivated habitat, Chumbi Surla Wildlife Sanctuary.

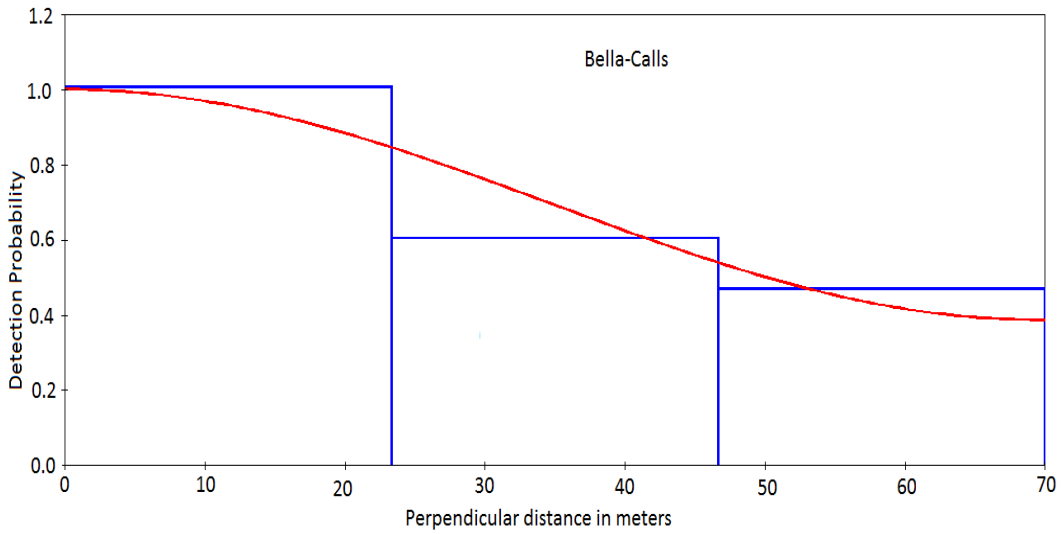

Figure 4.19 : Distance function curve for Grey Francolin calls in openland habitat, Chumbi Surla Wildlife Sanctuary.

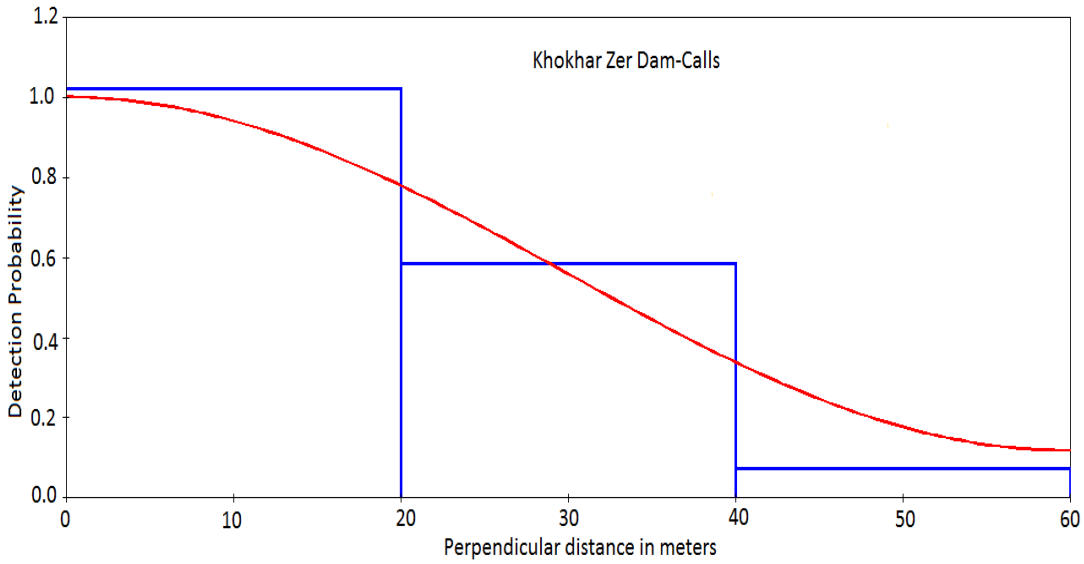

Figure 4.20 : Distance function curve for Grey Francolin calls in wetland habitat, Chumbi Surla Wildlife Sanctuary.

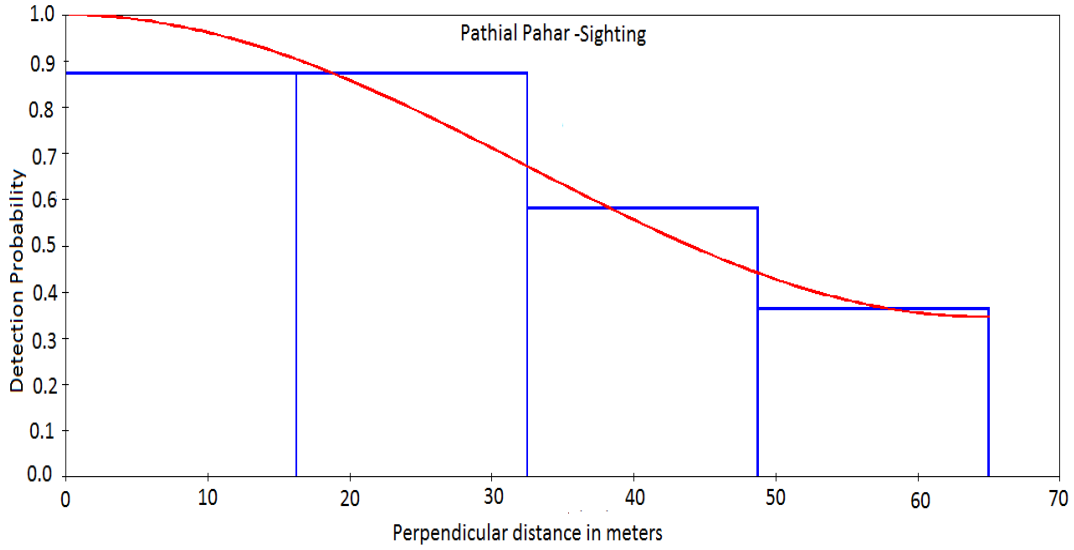

Figure 4.21: Distance function curve for Grey Francolin sightings in natural forest habitat, Diljabba Domeli Game Reserve.

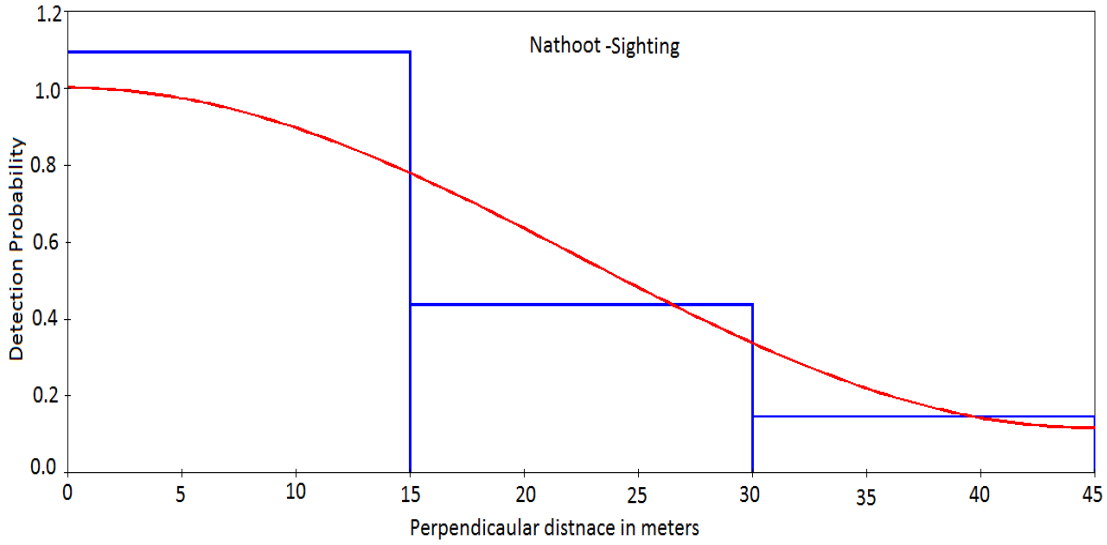

Figure 4.22: Distance function curve for Grey Francolin sightings in cultivated habitat, Diljabba Domeli Game Reserve.

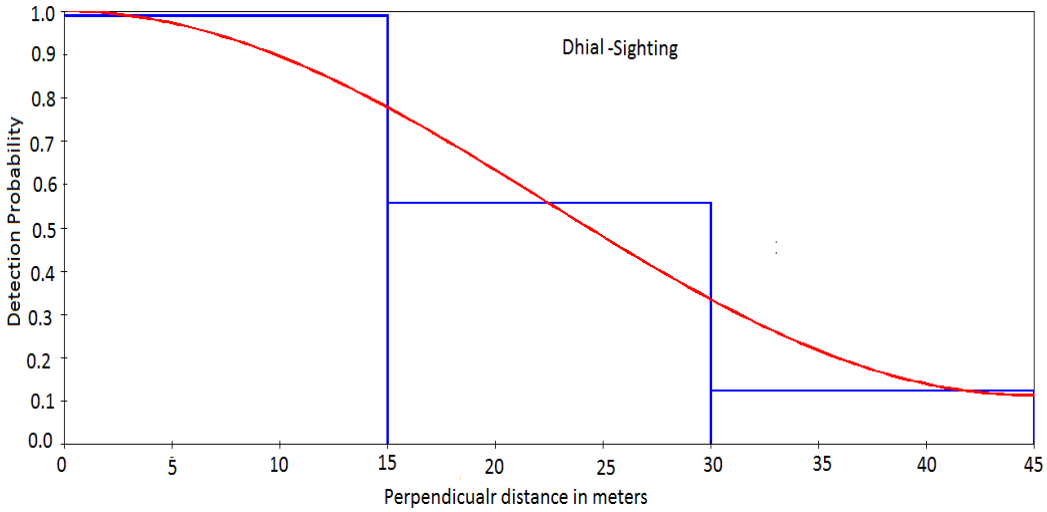

Figure 4.23: Distance function curve for Grey Francolin sightings in openland habitat, Diljabba Domeli Game Reserve.

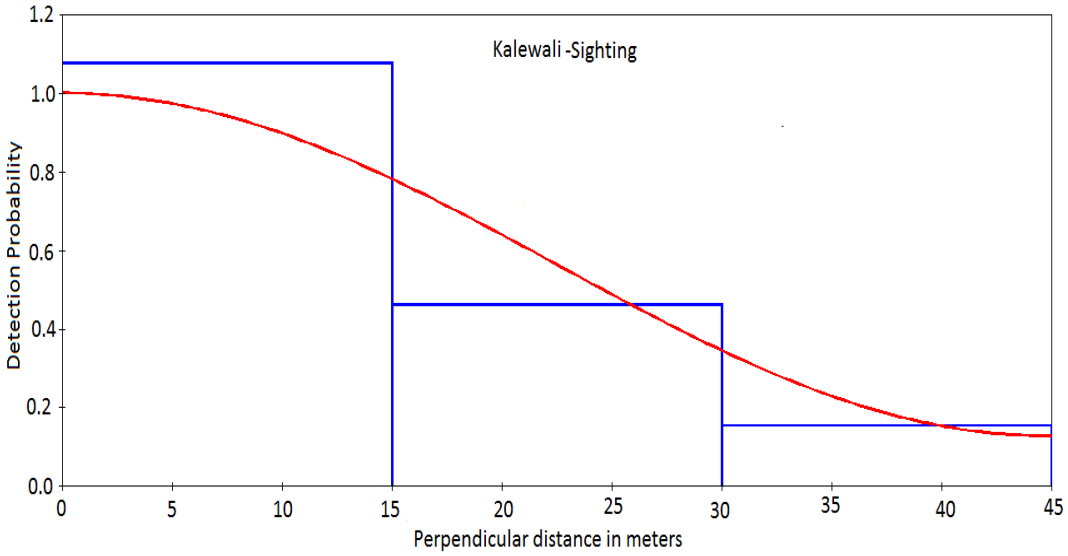

Figure 4.24: Distance function curve for Grey Francolin sightings in wetland habitat, Diljabba Domeli Game Reserve.

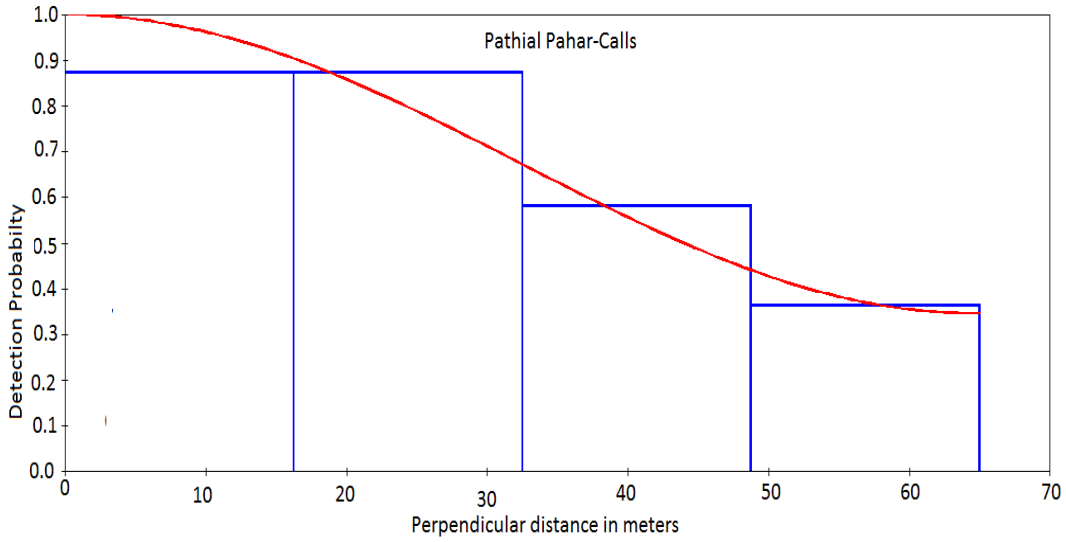

Figure 4.25: Distance function curve for Grey Francolin calls in natural forest Habitat, Diljabba Domeli Game Reserve.

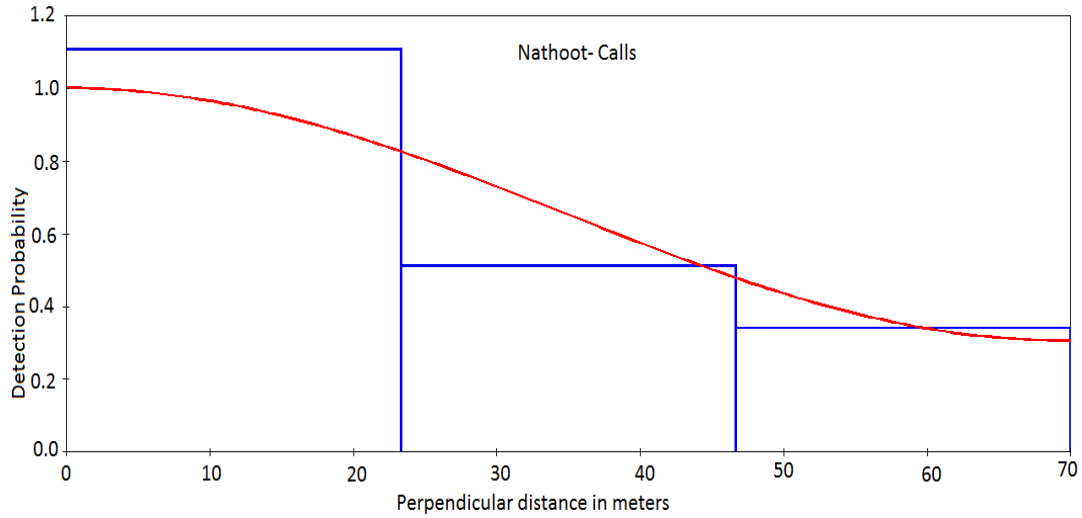

Figure 4.26: Distance function curve for Grey Francolin calls in cultivated Habitat, Diljabba Domeli Game Reserve.

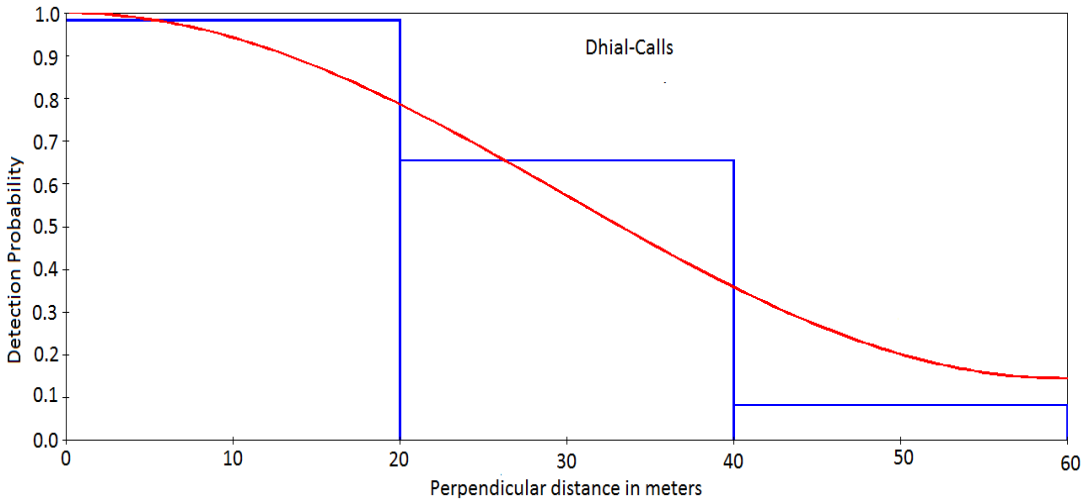

Figure 4.27: Distance function curve for Grey Francolin calls in openland habitat, Diljabba Domeli Game Reserve.

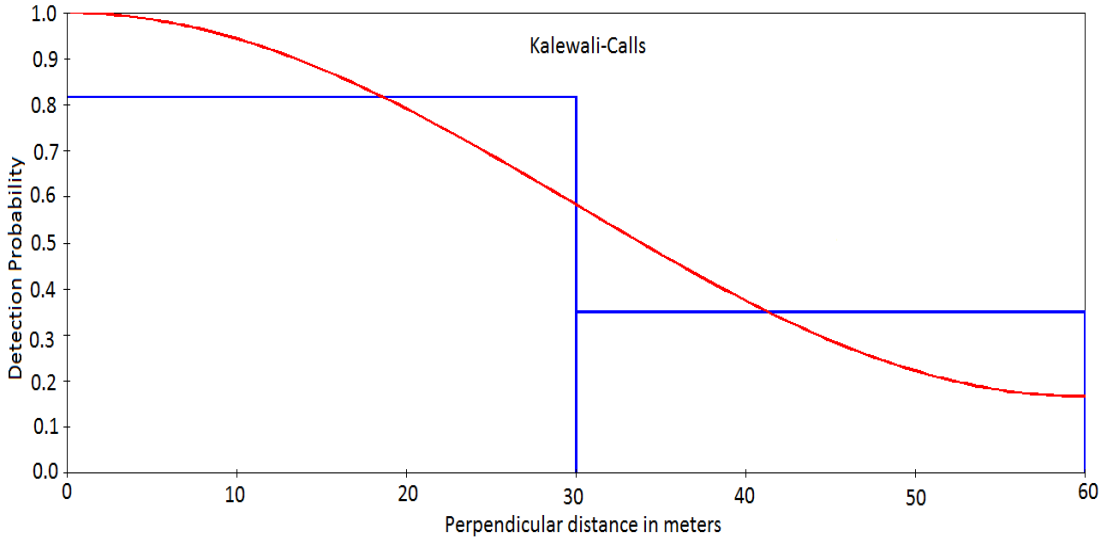

Figure 4.28: Distance function curve for Grey Francolin calls in wetland habitat, Diljabba Domeli Game Reserve.

Khan (2010) estimated 7.44 birds / km² in LSNP under same desert conditions. According to this study variation in frequencies of calls were prominent as compared to sighting in same area. The difference in population density figures of Grey francolin in this study and that reported previously for LSNP can be associated to variation in sampling designs of both studies. Wijeyamohan *et al.,* (2003) has been reported for the Mannar, Sri Lanka, a relatively low density of population of 3.5 / km² birds for the Grey francolin.

By calls method, the highest density was found at Dhok Sehla (2.87 individual ha^{-1} (95% CI: 0.56 and 1.00), that was natural forest while again lowest density was in Subedarawali Mori at 1.59 individual ha^{-1} shows that Grey francolin has low preference for this type of habitat that has only cultivated crops without water source and scarce natural vegetation in CSWS.

In DDGR by sighting, highest density was estimated for Kalewali (2.47 individual ha^{-1}) which was a wetland area with thick natural vegetation on its boundaries. This indicates that species prefers the habitat having water and thick vegetation, which provides cover for them. Lowest record was (2.09 individual ha^{-1}) from Pathial Pahar that was a pure natural forest but have disturbance because of road construction around it during the study period. By calls method, highest density was at Dhial (2.45 individual ha^{-1}) that was an open land with natural vegetation around it while lowest calls was recorded from Kalewali (1.10 individual ha^{-1}). Population

density recorded by sighting and by calls show difference among different sites. A similar study carried in the agricultural land and wetlnd in the Faisalabad (Central Punjab, Pakistan) utilizing call count method, suggested average densities of 395 birds/ km^2 having range from 90 – 655 birds for the Grey francolin did not tried to give density values (Ullah, 1991).

The results indicated that Grey francolin prefers areas with vegetation cover and water source which provide better habitat to live in a particular place. These findings are supported by Salek *et al.* (2004) proposed that high density of wild Grey Partridge (*Perdix perdix*) were related with the presence of herbaceous land, unmanaged wild areas and farm land around it in Prague, the Czech Republic. Moreover, estimations of density, analysis of home range, sampling of weed seed and study of plant structure factors affect the francolin's habitat preference.

Transect sampling and call counts have been utilized for population studies in different francolin species (Howman and Garson, 1993; Abbasi and Khan, 2004, Mahmood *et al*., 2010; Khan, 2010; Hussain *et al*., 2012) to reach at some reliable estimates on the populations. Call counts in spring season were considered as more dependable sign to record the breeding pairs/ birds in population of Grey partridge (*Perdix perdix*) (Weigand, 1977), though such estimates were not considered reliable for other parts of the year. The technique of counting the birds through call affected by changes in season, temperatures, conditions of availability of habitat and food, male

activity of reproduction as well as density of males. Such problems have been addressed earlier in call count method as relevant to pheasants (Gaston, 1980; Davison, 1983; Young *et al*., 1987; Picozzi, 1987; McGowan, 1992; McGowan *et al*., 1996; Howman and Garson, 1993; Sankaran, 1994; Kaul and Shakya, 2001; Abbasi and Khan, 2004). The number of the calling birds has been reflected by call counts, and therefore stated as the frequency of calling males (Nijman, 1998; Winarni *et al*., 2009) or birds in pair form (Panek, 2005; Bealey *et al.*, 2006), of distinct bird species. However, under the conditions of Salt Range, in CSWS and DDGR, in scrub forest the sighting on the transect line for estimations of population seems to be a more reliable method particularly, when the width of the transect belt is limited. Results obtained by calls count are different from the results of direct sightings. This difference may be due to camouflage ability of the grey francolin in different conditions. Fuller *et al*., (2000) concluded that sightings of the francolins species, living under thick cover of plants, mainly based upon searching a shelter along some vegetation for its protection, and possessing shy behavior under a higher level of disturbance adds difficulties in the transect sightings.

During the study, groups of 4 to 12 francolins were observed in CSWS and DDGR, particularly shortly before breeding season. Grimmett *et al*., (1998) and Wijeyamohan et *al*., (2003) also reported that during non breeding season, Grey francolins are mostly found in coveys form of 4-8 birds or family groups were also known, which during breeding season makes pairing. Populations of Grey francolin

recorded from CSWS were found higher as compared to DDGR, probably because of more protection of the area as sanctuary, where grey francolin assumed more protected.

4.3 BREEDING STUDY OF GREY FRANCOLIN IN SALT RANGE, PUNJAB

4.3.1 Breeding Biology in Chumbi Surla Wildlife Sanctuary (CSWS) and Diljabba Domeli Game Reserve (DDGR)

Ten nests of Grey francolin; six in natural forest and four in crop cultivated fields were located during the study period. All nests were found on the ground in the vegetation which mainly consisting of *Cynodon dactylon, Desmostachia bipinnata, Ziziphus jujuba, Dalbergia sissoo, Acacia modesta* and *Acacia nilotica* (Table 4.18). Shape of the nest varied from round to oblong in both cultivated and forest habitat (Plate 4.1). In natural forest habitats, mean outer diameter of the nests was17.54$\pm$1.04 cm (15.24- 21.18 cm) while inner diameter was 13.09$\pm$1.20 cm (10.16-17.78 cm). In cultivated fields, outer diameter of nest was 19.97+2.08cm (15.21-25.34cm) and inner 17.41+2.37cm (13.23-22.86cm). However, no significant difference was found in nest diameters between the two habitats (outer diameter, ANOVA: $F = 1.34$; $df = 1$; $P = 0.27$; inner diameter, ANOVA: $F = 3.22$; $df = 1$; $P = 0.11$).

Mean weight of eggs was 10.39$\pm$0.87 gm (8-14 gm) in forest habitat and 13.6$\pm$ 1.80gm (8-15 gm) in cultivated habitat, mean length was 29.39$\pm$0.93 mm (25-32 mm) in forest habitat and 41.05+3.7 (30-46 mm) in cultivated habitat, mean width was

25.62±2.11mm (16-35 mm) and mean volume in natural forest habitat was 645.63±55.24 (425-805 mm^2) and in cultivated habitat was 1339.95±233.27 (653-1671mm^2).The weight of eggs (ANOVA: F = 2.21; df = 1; P = 0.17) was the same between the habitats; however, egg length (ANOVA: F = 14.439; df = 1; P = 0.005238), egg width (ANOVA: F= 9.7207; df = 1; P = 0.01428) and volume of the eggs (ANOVA: F = 4.09; df = 1; P = 0.18) had higher values in the cultivated habitat.

Color of eggs was dusty white to pink with white spots on it, and texture was somewhat rough and smooth, while shape of eggs was oval. There was no difference in the shape of nest (χ^2= 0.28; df = 2; P = 0.87), color of the egg (χ^2= 4.09; df = 3; P = 0.25) and surface texture of the egg (χ^2= 0.623; df = 1; P = 0.43) found from cultivated and natural forest habitats (Table 4.19). The mean egg laying period was 12.1±1.20 days (range 7-18 days) and was similar between the habitats (ANOVA: F= 1.2878; df= 1; P = 0.2893).The mean clutch size was 6.8±0.78 (range 4-12 eggs) indicating that this population probably lay eggs on alternate days, with no difference of number of eggs between the habitats (ANOVA: F = 0.499; df =1; P = 0.49) (Plate 4.2). A nest with four eggs without female was found, which might have been killed during incubation, as a result all eggs was destroyed. The average incubation period recorded in the present study was 15.7±1.86 (range 13-20 days), similar in both habitats (ANOVA: F = 0.7; df = 1; P = 0.42) and both sexes were observed taking part in incubation. Out of a total of 68 eggs recorded in various nests, 53 were hatched (74.80

Table 4.18: Location and constituents of nesting material of Grey Francolin in Salt Range.

Nest No.	Habitat type	Elevation (m)	Nest material	Vegetation around nest location
1	Natural Forest	523	*Desmostachia bipinnata,*	*Acacia nilotica*
2	Natural Forest	655	*Cynodon dactylon, Desmostachia bipinnata*	*Ziziphus jujuba*
3	Natural Forest	398	*Desmostachia bipinnata, Acacia nilotica*	*Acacia nilotica, Ziziphus jujuba*
4	Natural Forest	677	*Desmostachia bipinnata, Cynodon dactylon*	*Ziziphus jujuba,*
5	Cultivated field	539	On ground in soil with *Dalbegia sissoo* leaves	*Dalbergia sissoo, Ziziphus jujuba on field Edge*
6	Cultivated field	704	*Desmostachia bipinnata*	*Ziziphus jujuba*
7	Natural Forest	367	*Desmostachia bipinnata, Acacia modesta*	*Acacia modesta, Ziziphus jujuba*
8	Cultivated field	417	*Desmostachia bipinnata*	*Ziziphus jujuba,*
9	Natural Forest	707	*Desmostachia bipinnata*	*Ziziphus jujuba, Acacia nilotica*
10	Cultivated field	463	*Desmostachia bipinnata*	*Ziziphus jujuba, Acacia modesta on field edge*

% success) with a mean rate of hatching 5.3±0.85 eggs per clutch and with similar success between the habitats (ANOVA: F = 0.03; df = 1; P = 0.86). The fledging success was estimated at 4.6±0.81 per clutch indicating an overall success of 77%, similar for both habitat types (ANOVA: F = 0.14; df = 1; P = 0.71). (Table 4.20; Figure 4. 29). Some additional observations suggested that Grey francolin usually change their nesting sites in each breeding season. Female gives its egg′s membrane as first feed to her chicks. Chicks feed on termites from their hatching up to four weeks of age and avoid drinking water as it is considered harmful for their survival. Male also remains with the female after incubation and take part in raising the chicks (Plate 4.3). *Accipiter nisus* and *Echis carinatus* were found among top predators of Grey francolin in the study area. Black francolin shares the same habitat with Grey francolin, so can be a competitor for resources.

Present study revealed that all nests of Grey francolin were located on the ground in natural vegetation having dominant species such as *Ziziphus jujuba, Acacia modesta, Acacia nilotica, Dalbergia sissoo, Desmostachia bipinnata* and *Cynodon dactylon.* These findings are in agreement with Hussain *et al.,* (2012) who reported that nests of Gray francolin are mostly made with *Desmostachia bipinnata, Acacia modesta, Ziziphus jujuba, Euphorbia spp.* and *Imperata cylindrica* in agro-ecosystem of Pothwar Pleatue, Punjab. Similarly, Roberts (1991) reported that nest of Grey francolin is well concealed inside a clump of grass growing up through a thorn bush and it is merely a depression on the ground having a few blades of dead leaves.

Table 4.19: Measurements of nests and eggs in natural forest and crop cultivated habitat of Salt Range.

Nest No. (Habitat type)	Shape of Nest	Outer diameter of Nest (cm)	Inner diameter of Nest (cm)	Shape of eggs	Color of eggs	Surface texture	Weight of egg (gm)	Lengthof egg (mm)	Width of egg (mm)	Volume of egg (mm^2)
1 (Forest)	Oblong	20.32	10.16	Oval	Pink with white spot	Somewhat rough	14.45	25.4	16.77	425.95
2 (Forest)	Partial Round	16.51	11.91	Oval	Pink with white spot	Somewhat rough	8.67	28.54	20	570.80
3 (Forest)	True round	15.24	11.07	Oval	Dusty white	Smooth	9.79	30.24	24.65	745.41
4 (Forest)	Partial round	21.18	15.57	Oval	Pinky white	Smooth	9.29	29.87	21.23	634.14
5 (Forest)	True round	15.51	12.09	Oval	Pink with white spot	Somewhat rough	9.11	30.11	23	692.53
6 (Forest)	Oblong	16.51	17.78	Oval	Dusty	Smooth	11.03	32.20	25	805.00

Continue…

… Table 4.19 continued

Nest No. (Habitat type)	Shape of Nest	Outer diameter of Nest (cm)	Inner diameter of Nest (cm)	Shape of eggs	Color of eggs	Surface texture	Weight of egg (gm)	Length of egg (mm)	Width of egg (mm)	Volume of egg (mm^2)
Mean±S.E		17.54±1.04	13.09±1.20				10.39±0.87	29.39±0.93	21.75±1.27	645.63±55.24
7 (Cultivated)	Oblong	19.30	13.23	Oval	Pink with white spot	Somewhat rough	16.89	46.88	35.65	1671.27
8 (Cultivated)	True round	25.34	19.93	Oval	white	Smooth	8.72	30.48	21.45	653.79
9 (Cultivated)	Oblong	15.21	13.63	Oval	white	Smooth	11.66	43.18	33.55	1448.68
10 (Cultivated)	Partial round	20.06	22.86	Oval	Dusty white	Smooth	15	45.46	34.89	1586.09
Mean±S.E		19.97±2.08	17.41±2.37				13.06±1.80	41.05±3.75	31.38±3.33	1339.95±233.27
	(χ^2= 0.28, df = 2, P = 0.87).	(F = 1.34, df = 1, P = 0.28).	(F = 3.22, df = 1, P = 0.11).		(χ^2= 4.09, df = 3, P = 0.25).	(χ^2= 0.623, df = 1. P = 0.43).	(F = 2.21, df = 1, P = 0.17).	(F = 14.44, df = 1, P = 0.05).	(F = 1.34, df = 1; P = 0.28).	(F = 4.09, df = 1; P = 0.18).

Table 4.20: Breeding pattern of Grey Francolin in different habitats of Salt Range.

Nest No. (Habitat type)	Egg laying period (days)	Clutch size	Incubation period	Hatching Success	Fledging success
1 (Forest)	7	4	15	4(100%)	4 (66%)
2 (Forest)	9	6	19	4(66%)	3(66%)
3 (Forest)	15	9	18	8(66.66%)	6(66%)
4 (Forest)	9	5	17	4(66.66%)	2(66%)
5 (Cultivated)*	8	4	0	0(0%)	0(0%)
6 (Cultivated)	16	12	18	10(83.33%)	9(90%)
7 (Forest)	15	8	20	6(75%)	6(100%)
8 (Cultivated)	13	6	19	5(83.33%)	4(80%)
9 (Forest)	11	6	13	5(83.33%)	5(100%)
10 (Cultivated)	18	8	18	7(87.5%)	7(100%)
Mean±S.E	12.1±1.20	6.8±0.78	15.7±1.86	5.3±0.85(74.80%)	4.6±0.81(77%)
ANOVA Values	(F = 1.29, df = 1; P = 0.28).	(F = 0.5, df = 1; P = 0.49).	(F = 0.7, df = 1; P = 0.42).	(F = 0.03, df = 1; P = 0.86).	(F = 0.14, df = 1; P = 0.71).

*The female left the nest during incubation period.

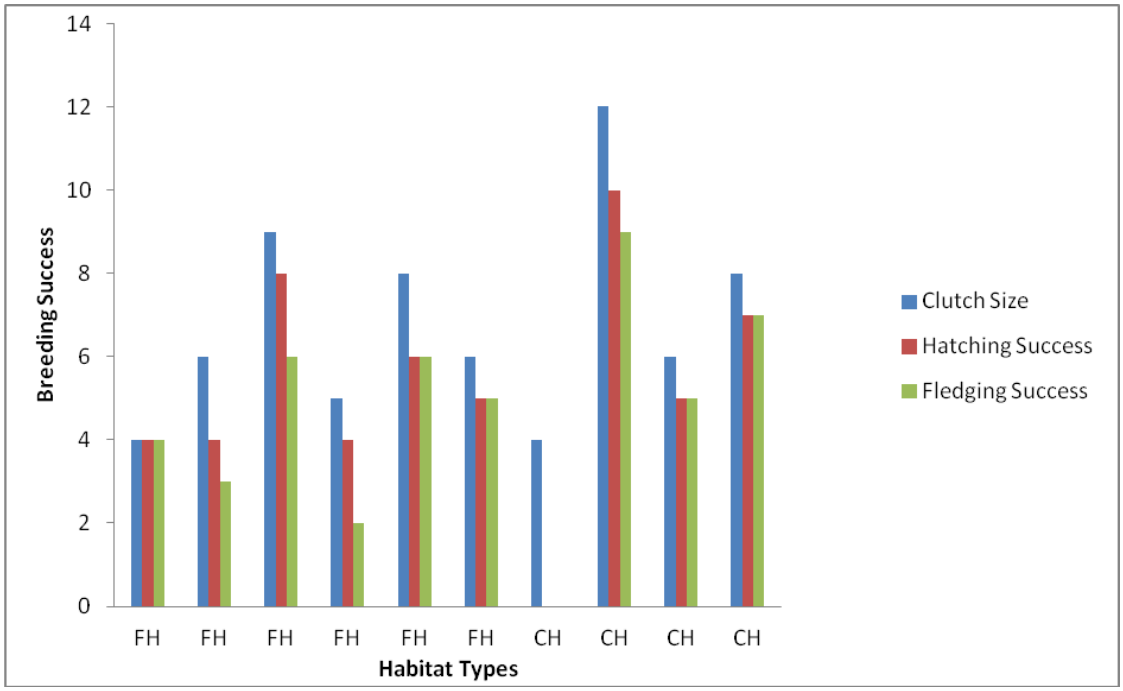

Figure 4.29: Breeding success (clutch size, hatching and fledging success) of Grey Francolin in Forest habitat (FH) and Cultivated habitat (CH), in Salt Range.

Sharma (1983) concluded that grasslands and plowed fields and *Euphorbia spp*. were selected as a nest site by Grey francolin during breeding season. Out of ten nests of Grey francolin located during the study, six were found in natural forest, which indicated that this species has little preference for natural vegetation to build it nest as compared to cultivated vegetation. Selects of natural forest during breeding season may be due to the reason that it provides cover and protection to the species from its predator better than in cultivated field. Results of previous studies on Grey francolin suggested that the hatching success is positively correlated with the vegetative cover as preferred sites for nesting were in permanent plant cover and orchards; use of crops was less frequent than expected. Carrying capacity of a habitat for grey partridge (*Perdix perdix*) depends on the availability of field edges (Panek and Kamieinarz, 2000). Grey partridge build nest in grassy cover that hides the nest from predation. Mostly, females conceal their nest in linear boundary features such as the base of hedgerows, grassy banks or uncut field margins (Aebischer *et al*., 1994).

The present study recorded the egg laying span from 13 April to 24 June which coincides with earlier observations in this regard i.e. from March to June (Trippenses, 1948) in London and from March to May in Pothwar Plateau (Hussain *et al*., 2012). In agriculture fields (Faisalabad, Pakistan) egg laying extended from March to September with peak from March to June, and maximum number of fledglings appeared in April to June (Ullah, 1991). The mean egg laying period of 12.1$\pm$1.20 days and average clutch size of 6.8$\pm$0.78 eggs in the present study suggested that this population probably laid eggs with one day interval. Study of breeding behavior of this species in

desert area of Pakistan by Khan (2010) supports this data who reported Grey francolin did not lay egg daily and requires double duration than its clutch size to complete it.

Shape of nest varied from round to elongate. Outer and inner diameter of grey francolin's egg in cultivated and natural forest habitat was found same. Color of the egg was dusty white to pink with white spots on it and texture was somewhat rough and smooth, while shape of the egg was oval in both habitat types. Layard (1854) reported that female francolin in Ceylon, laid olive-green eggs, robust at one end and sharp at the other. Hussain *et al*., (2012) observed that eggs were oval in shape and pale brown in color. In present study, in both cultivated and natural forest habitat, shape, inner and outer diameter of the nest, color, shape, texture, and weight, of the egg was same, but, egg length, egg width and egg volume was different in both natural and cultivated habitat as egg width, length and volume had higher values in cultivated habitat as compared to natural forest, probably due to better food availability in the form seeds and leaves of crops; *Eruca sativa*, *Arachis hypogaea*, *Brassica compestris*, than forest habitat. No earlier record found on these aspects of Grey francolin, it was difficult to compare this data with previous studies.

Clutch sizes (4-12eggs) recorded in present study is in accordance with the observation of Baker (1921) 4-10 eggs, Clark (1901) 8-10eggs, Hussain *et al*.,(2012) 6-8 eggs, Sharma (1983) 6-7 eggs, and Khan (2010) 2-13 eggs. Maximum number of 12 eggs was recorded in a nest situated in cultivated field having natural boundary vegetation which suggests that bird living near good food source have higher clutch size. This data is also in conformation with that of Hussain *et al*. (2012), where nest

located in cultivated habitat have higher number of eggs i.e. 8 eggs. This has also been documented from agricultural farms of Rajasthan, India by Sharma (1983) that food availability affects clutch size. Average incubation period 15.7±1.86days (range 13-20days) recorded during present study supports the earlier findings by Khan (2010) in desert population of Gray francolin, which is 16-21 days. It also agrees with the values 18-21 days recorded by Bump and Bump (1964); Ali and Ripley (1983), Roberts (1991) and Hussain *et al*., (2012) for Grey francolin which is in the range of 19-22 days.

The hatching success (74.80%) recorded in this study with a mean hatching rate of 5.3±0.85 eggs per clutch is higher than that reported by Khan (2010) which was 44.0± 3.36 % (4.76± 0.97) and Panek (2005) which was 29-49%. However, it was similar to as reported by Hussain *et al*., (2012) with a mean hatching rate of 5.33 ± 1.22 eggs per clutch (76.19% success). Similarly, fledging success (77%) estimated at 4.6±0.81 per clutch in this study is also little higher than that of Panek (2005) which was 31 to 56% (43.1%) and Khan (2010) who reported 37.0±3.25 % and Hussain *et al*., (2012) who estimated at 3.83 ± 0.83 per clutch (63.08%). According to Khan (2010), average clutch size and number of nestling and fledglings increases with higher rainfall. Higher reproduction success in Salt Range may be due to higher mean annual rainfall than that of desert habitat. Present study revealed that Grey francolin is mainly associated with natural vegetation and crop cultivated fields situated around natural vegetation for breeding in Salt Range. Hence, its population can be maintained by improving the natural vegetation cover in its habitat.

4.4 THREAT STUDY OF GREY FRANCOLIN IN SALT RANGE

4.4.1 Threat Identification of Grey francolin in Chumbi Surla Wildlife Sanctuary (CSWS) and Diljabba Domeli Game Reserve (DDGR)

This study was based on questionnaire survey where information about various threats to population and habitat of Grey francolin was collected in both study sites (Plate 4.4).

4.4.1.1 Age

For the survey, respondents were categorized into six age group i.e. 15-25, 25-35, 35-45, 45-55, 55-65 and 65-75 years.

In Chumbi Surla Wildlife Sanctuary 20% respondents belonged to age group of 15-25, 14% of 25-35, 14% of 35-45, 26 % of 45-55, 10% of 55-65 and 16 % of 65-75 (Table 4.21). In Diljabba Domeli Game Reserve, 14 % respondents were of age group of 15-25, 24% of 25-35, 28% of 35-45, 18 % of 45-55, 10% of 55-65 and 6 % of 65-75 (Table 4.22, Figure 4.30).

4.4.1.2 Occupation

In both protected areas, most of the respondents were engaged in agriculture, livestock rearing, government jobs and shopkeeper. In Chumbi Surla Wildlife Sanctuary, 34% respondents were farmers, 14% shopkeepers, 12% livestock owners, 22% hunters, 10% Government employeess and 8 % were in Fisheries and Wildlife Department. In Diljabba Domeli Game Reserve, 18 % were farmers, 22% shopkeepers, 36% livestock owners, 8% hunters, 8% Government employees and 8 % engaged in Fisheries and Wildlife Department (Figure 4.31).

4.4.1.3 Population trend of Grey francolin

In Chumbi Surla Wildlife Sanctuary, 36% respondents were of the view that population of grey francolin is increasing after designation of the area as sanctuary, while 38% said that population is declining and, 14 % said that population is stable in sanctuary areas due to control hunting, especially in core zone where all such activities are prohibited. In Diljabba Domeli Game Reserve, 30% respondents said that population is increasing, according to 44% population is decreasing, 16 % people said that population is stable in reserve due to controlled hunting and 10% people were unaware (Figure 4.32).

4.4.1.4 Major Threats to Grey francolin population and its habitat in the study area

Keeping in view the declining trend of Grey francolin in the study area, major threats affecting grey francolin in both CSWS and DDGR were identified as hunting, trade, habitat destruction, predation, livestock pressure, agriculture, collection of fuel wood, land clearing and stone crushing. Major threat in Chumbi Surla Wildlife Sanctuary included; 38% by illegal hunting , 06% by trade, 06% by habitat destruction, 04% by predation, 04 % by live stock pressure, 04% by fuel wood collection,18% by land clearing, 02% by stone crushing and 18 % by agriculture in the protected areas.

Similarly, these threat in Diljabba Domeli Game Reserve were; 46% by illegal hunting , 04% by trade, 02% by habitat destruction, 04% by predation, 04 % by

Table 4. 21: Threat assessment of Grey Francolin in Chumbi Surla Wildlife Sanctuary.

S.No.	Questions for Threat Assessment	Number of respondents	Percentage (%)
1	**Age of Respondents**		
	15-25	10	20
	25-35	7	14
	35-45	7	14
	45-55	13	26
	55-65	5	10
	65-75	8	16
2	**Occupation**		
	Farmer	17	34
	ShopKeeper	7	14
	Live Stock Owner	6	12
	Hunter	11	22
	Job	5	10
	Wildlife Watcher	4	8
3	**Population Trend of Grey Francolin**		
	Increasing	18	36
	Decreasing	19	38
	Stable	7	14
	Unknown	6	12
4	**Hunting Methods**		
	Shooting	27	54
	Netting	8	16
	Trapping	15	30
5	**Trade Life Stage**		
	Egg	11	22
	Chick	21	42
	Sub-Adult	13	26
	Adult	5	10
6	**Predator of Grey Francolin**		
	Canis aureus	2	4
	Accipiter nisus	18	36
	Herpestes edwardsii	14	28
	Echis carinatus	3	6
	Vulpus vulpus	10	20
	Felis chaus	1	2
	Varanus bengalensis	2	4

Table 4. 22: Threat assessment of Grey Francolin in Diljabba Domeli Game Reserve.

S.No.	Questions for Threat Assessment	Number of respondents	Percentage (%)
1	**Age of Respondents**		
	15-25	7	14
	25-35	12	24
	35-45	14	28
	45-55	9	18
	55-65	5	10
	65-75	3	6
2	**Occupation**		
	Farmer	9	18
	ShopKeeper	11	22
	Live Stock Owner	18	36
	Hunter	4	8
	Job	4	8
	Wildlife Watcher	4	8
3	**Population Trend of Grey Francolin**		
	Increasing	15	30
	Decreasing	22	44
	Stable	8	16
	Unknown	5	10
4	**Hunting Methods**		
	Shooting	29	58
	Netting	14	28
	Trapping	7	14
5	**Trade Life Stage**		
	Egg	5	10
	Chick	30	60
	Sub-Adult	5	10
	Adult	10	20
6	**Predator of Grey Francolin**		
	Accipiter nisus	37	74
	Herpestes edwardsii	5	10
	Echis carinatus	2	4
	Varanus bengalensis	6	12

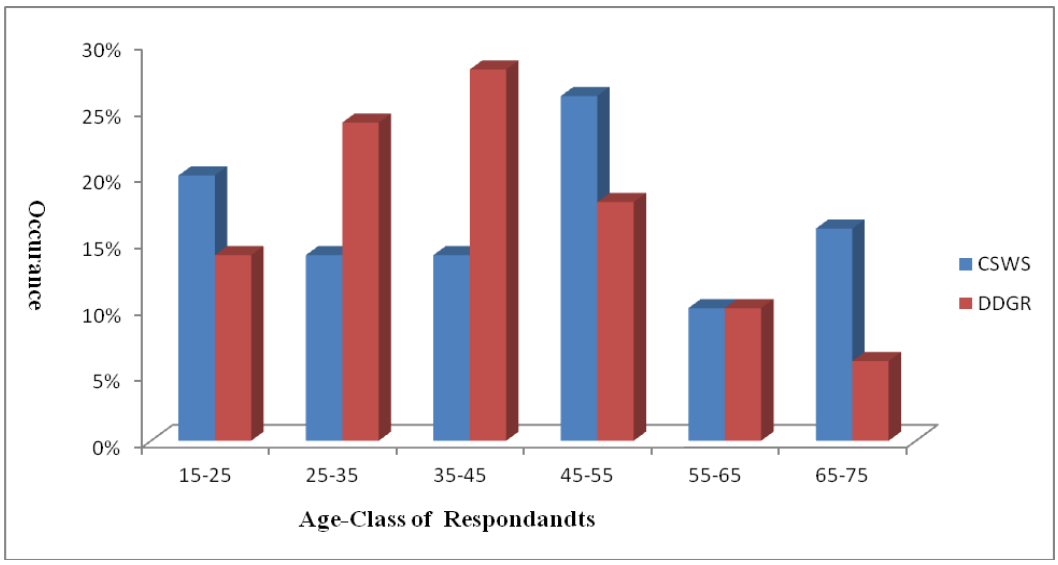

Figure 4. 30: Age classes of Respondents to Grey Francolin's questionnaire survey in CSWS and DDGR.

Figure 4. 31: Occupation of respondents in study area of CSWS and DDGR.

livestock pressure, 18 % by agriculture, 16% by fuel wood collection, 04% land clearing and 2% by stone crushing (Figure 4.33).

Chi square test was used to find out whether all threats contributed equally or not in both CSWS and DDGR. Level of significance was 0.05 % with 8 degree of freedom. The Chi-square value is a single number that adds up all the differences between actual data and the data expected if there is no difference. Greater differences between expected and actual data produce a larger Chi-square value. The larger the Chi-square value, the greater the probability that there really is a significant difference (Random ORG, 1998).

In present study, actual values recorded in CSWS for various categories of threats; 19(hunting), 3 (trade), 3 (habitat destruction), 2 (predation), 2 (livestock pressure), 9(agriculture), 2 (fuelwood collection), 9 (land clearing) and 1(stone crushing). Similarly, actual values of threat in DDGR were; 23 (hunting), 2 (trade), 1 (habitat destruction), 2 (predation), 2 (livestock pressure), 9 (agriculture), 8 (fuel wood collection), 2 (land clearing) and1(stone crushing) (Table 4.23). Value of Chi-square for the different threats in CSWS and DDGR indicating that all threats are significantly different from each other and did not contribute equally. Pearson Chi square value X^2=0.292 is greater than 0.05.So we accept our null hypothesis that threats and location are independent of each other and there is no significant difference between tthreats with respect to area. Different threats effect differently on grey francolin population in the study area (Table 4.24).

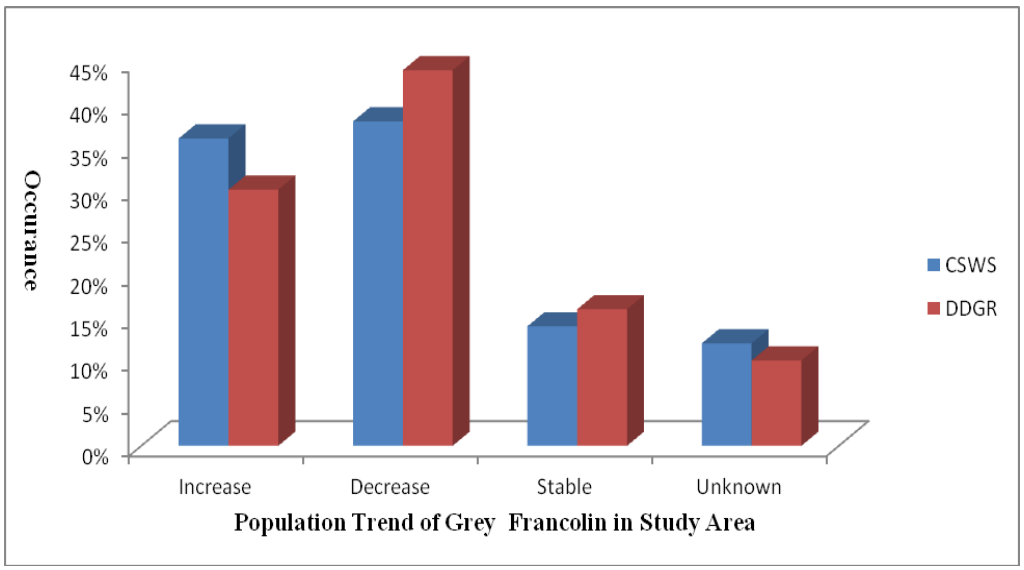

Figure 4. 32: Grey Francolin population trend in study area of CSWS and DDGR.

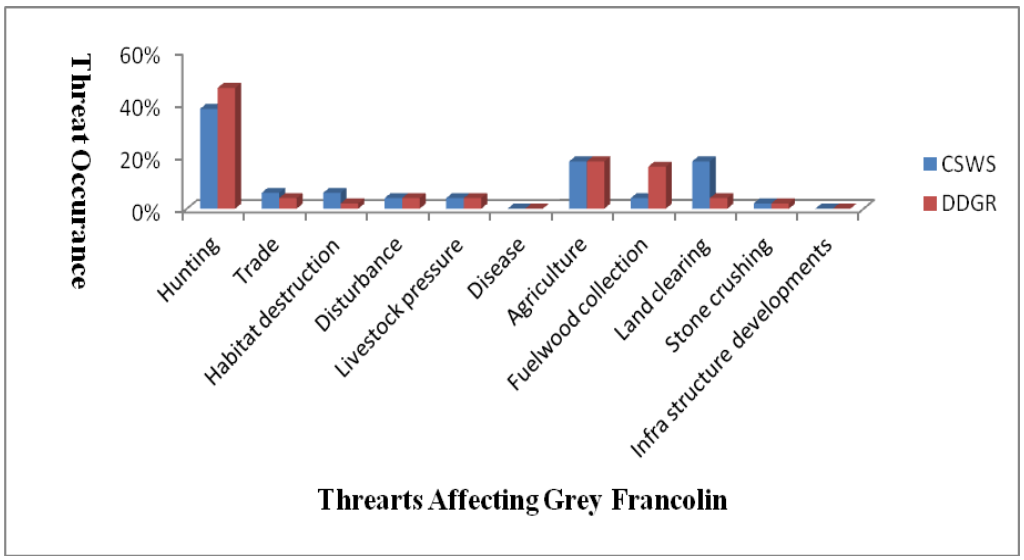

Figure 4. 33: Threats faced by Grey Francolin in study area of CSWS and DDGR.

4.4.1.5 Hunting methods

Different hunting methods used for Grey francolin in the study area included; shooting with bore guns, trapping by setting traps in potential feeding sites of grey francolin, hunting with trained dogs and use of nets. In Chumbi Surla Wildlife Sanctuary, major hunting method as told by respondents was: 54% shooting, 16% major hunting practice, followed by 28% netting and14 % trapping (Figure 4.34).

4.4.1.6 Trade life stage

Trade of Grey francolin is common in both study areas particularly during and after breeding season of the species. In CSWS, the life stage at which trade of species mostly occurred was chick stage shortly after hatching. As per people's opinion: 22% at egg stage, 42% at chick stage, 26% at sub adult and 10% at adult stage. In DDGR, trade was common (10%) at egg stage, while 60% by chick stage, 10% by sub adult and 20% by adult stage (Figure 4.35).

4.4.1.7 Predators of Grey Francolin

Predation of Grey francolin by different groups of animals was commonly reported in the area. Major predators reported during study period included; Jackal, (*Canis aureus*), Hawk (*Accipiter nisus*), Mongoose (*Herpestes edwardsii*), Jungle cat (*Felis chaus*), Snake (*Echis carinatus*), Red fox (*Vulpus vulpus*) and Monitor lizard (*Varanus bengalensis*).

According to local people and wildlife staff different predator affect grey francolin population during different period of the year. Some species like monitor

Table 4. 23: Threats to Grey Francolin population in Chumbi Surla Wildlife Sanctuary and Diljabba Domeli Game Reserve.

	Location	CSWS		DDGR	
S.No.	Threats Categories	Observed N	Percentage (%)	Observed N	Percentage (%)
1	Hunting	19	38	23	46
2	Trade	3	6	2	4
3	Habitat destruction	3	6	1	2
4	Predation	2	4	2	4
5	Livestock pressure	2	4	2	4
6	Agriculture	9	18	9	18
7	Fuelwood collection	2	4	8	16
8	Land clearing	9	18	2	4
9	Stone crushing	1	2	1	2

Table 4.24: Test statistics showing results of Chi-Square in CSWS and DDGR.

	N	Pearson Chi-Square	df	Asymp.Sig.
Threats	100	9.635	8	0.292

lizard, snake and red fox prey upon grey francolin during breeding season as they feed on the eggs while predation by jackal, mongoose, jungle cat and hawk was common after breeding season of Grey francolin. In Chumbi Surla Wildlife Sanctuary, predation caused by different animals by people opinion was: 4% by jackal, 36% by hawk, 28% by mongoose, 6% by snake, 20% by red fox, 2% by jungle cat and 4% by monitor lizard. In Diljabba Domeli Game Reserve, 74% by hawk, 10% by mongoose, 4% by snake, and 12% by monitor lizard (Figure 4.36).

Present study revealed that illegal hunting is one of the major threats in both study sites which accounts for decline of Grey francolin by 38% in CSWS and 46% in DDGR. Similarly, an earlier study reported illegal hunting as major factor affecting francolin's population in irrigated forest plantations and sub-mountainous tract of the Punjab (Mann and Chaudry, 2000). Among different hunting methods used for Grey francolin, shooting with bore gun was common method of partridge hunting as it accounts 54% hunting in CSWS and 58% in DDGR. Shooting considered an indirect cause of the decline in grey partridge (*Perdix perdix*) in Europe and in the last few years farming incomes have fallen which has driven some farms to change in land use for hunting and shooting game birds. This has led to the concern that shooting is damaging the remaining stocks of wild grey partridges which may inadvertently be shot when hunting pheasants and red-legged partridges (Aesbischer and Ewald, 2004). In Italy, population of the partridge was falling dramatically since the change in agriculture but there was little to no change in the amount of shooting (Tout and Perco, 2000).

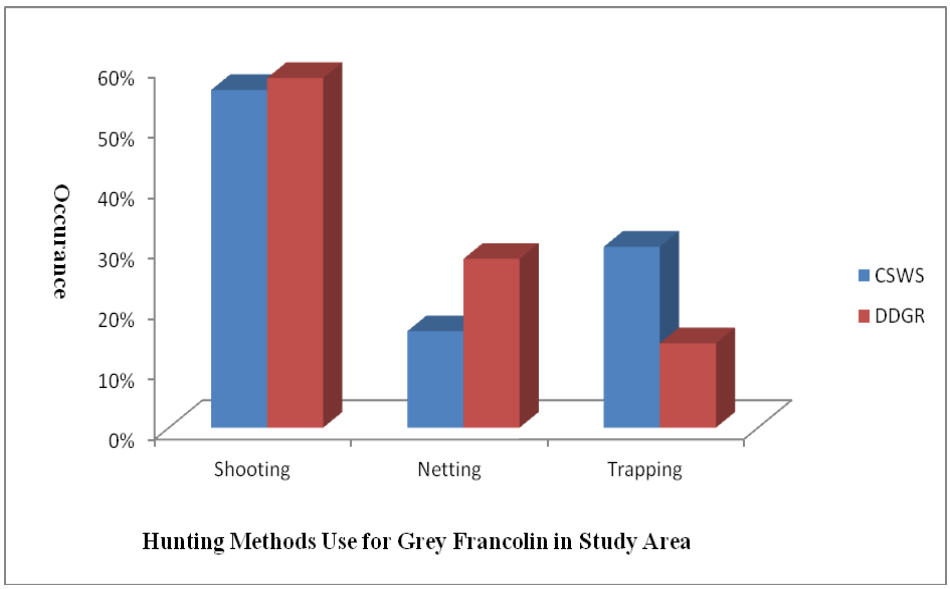

Figure 4. 34: Hunting methods used in study area of CSWS and DDGR for Grey Francolin.

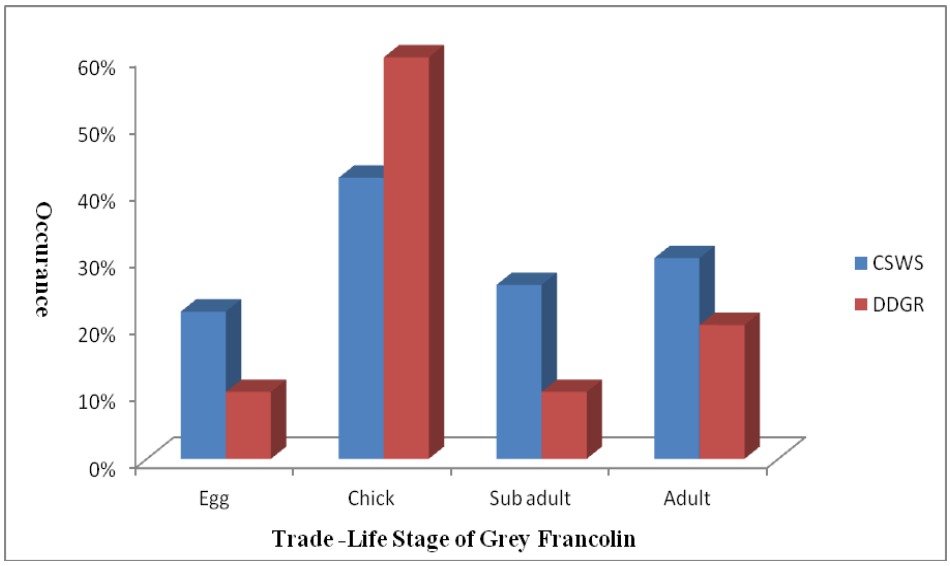

Figure 4. 35: Trade life stages of Grey Francolin in study area of CSWS and DDGR.

In France, where partridge shooting is popular as they were abundant especially where bag count as high as 5000 were recorded, breeding pair densities have been maintained only through a drastic reduction of shooting bags (Bro *et al.*, 2001). In the UK, at the turn of the century as many as 2 million birds were shot annually (Aesbischer and Ewald, 2004).

Because of its importance as a hunting bird there have been records kept about numbers for hundreds of years, for example spring counts to assess stocks were carried out in Austria since 1695. Commercial shooting often results in unintentional density-independent mortality of wild grey partridges because the number of shoot days depends on the number of game birds released, irrespective of wild grey partridge density. Considerable effort has been made to impose restrictions on shooting of grey partridges at low densities (Tapper, 2001).

Second highest threat causing decline of Grey francolin in study area was agriculture practices which contribute 18% in both CSWS and DDGR. As due to agricultural intensification, natural land is converted in to farmland, decreasing habitat of Grey francolin in the study area. Efficient farming practices caused more than 80%decline of partridge population in the UK since 1950‘s (Aebischer and Potts, 1995; Sotherton *et al.*, 2010) due to reduced chick survival caused by agricultural intensification and use of insecticides and herbicides In Europe, the problem is more severe due to long history of farming (BirdLife, 2004; Bro *et al.*, 2001).

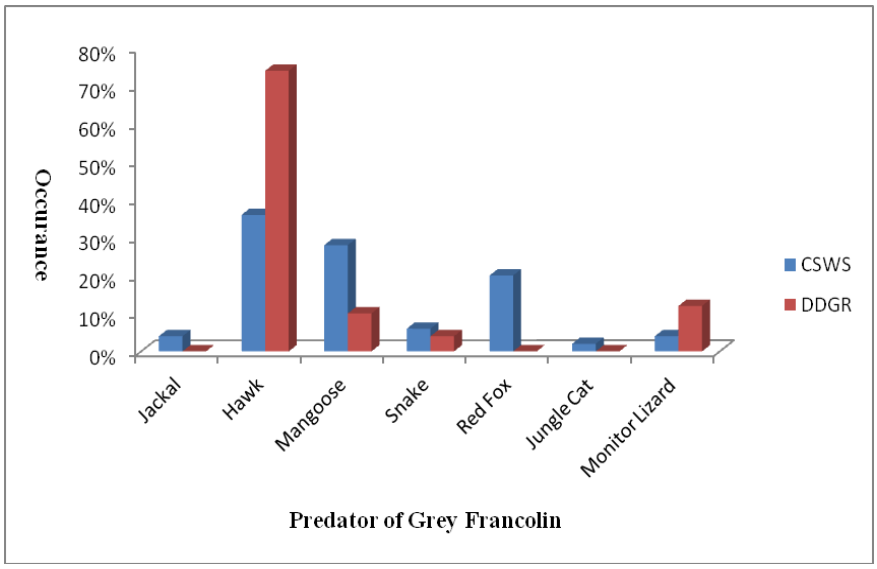

Figure 4. 36: Predator of Grey Francolin in study area of CSWS and DDGR.

Overall farmland birds in Europe have suffered larger decline than almost any other group. There has been an average decline of 44% from 1985 - 2005, compared to forest birds which have seen declines of roughly 9% (PECBMS, 2007). The future fate of Grey partridge in the UK rests on the balance between the economics of agricultural production, agri–environment measures and shooting (Aesbischer and Ewald, 2012). There was little to no use of machines in farming in past and the most of the work was carried out by hand or beast.

The introduction of mechanization into agriculture advances the industry, ploughing, sowing and reaping could all be done by one person in a much shorter time span. However, to accommodate the large machines and to give them room to manoeuvre fields were enlarged and vital partridge habitat went with it (De Leo *et al.*, 2004). Hedgerows were removed along with permanent vegetative cover which partridges would use for nesting (Aebischer and Potts, 1995; Bro *et al.*, 2001). The permanent vegetative cover is also an important source of food (e.g. insects and seeds) for partridge chicks and this has an impact on chick survival (Panek, 1997). This is also linked to predation; partridge predation rates are naturally high throughout the year and therefore the availability of cover is a key factor for partridge survival (Buner *et al.*, 2005). Partridge nests were and continue to be directly destroyed by farm machinery (Bro *et al.*, 2001; De Leo *et al.*, 2004).

Trade of Grey francolin at different life stages wss common in both protected area of CSWS and DDGR causing decline of the species as 6% decline in CSWS and

4% decline in DDGR was recorded. It was recorded that mostly trade occurs at the chick stage (42% in CSWS and 60% DDGR) than eggs, sub-adult or adult stage. There is no such evidence provided by previous studies that trade of species outside its home range causing decline of the species. Six percent decline in CSWS and 2% in DDGR reported by habitat destruction of the grey francolin due to urban expansion or increase in human population around both areas with the passage of time. Although this is not a main factor contributing to the population decline in Grey partridge but it still plays a role. This aspect is more common in Eastern Europe where there has been more intensive rural-urban migration (Aesbischer and Ewald, 2004).

Fuel wood collection is another cause of Grey francolin habitat degradation in both protected areas. Collection of wood is mainly done for fire and cooking purposes and trees are cut which ultimately destroyed vegetation cover for the species available as roosting sites in night time, it accounts 4% in CSWS and 6% in DDGR. Through food loss, excessive predation, habitat destruction, intensification of agricultural practices and other pressures on scrub forests for their use in fodder, timber wood and fire wood needs, a drastic decline in the natural habitat of grey francolin has been reported by Roberts (1991).

Some other factors recorded under current study were livestock grazing pressure, predation and stone crushing activity in the habitat of Grey francolin witch indirectly cause decline in its population as 6% decline in both areas by live stock pressure and predation while 2% decline by stone crush has been identified during

study from CSWS and DDGR. Livestock grazing indirectly affects the francolin's habitat by disturbing it and by putting pressure on the vegetation which is utilized by Grey francolin as its breeding ground. Major plant species affected due to livestock grazing in both areas were *Acacia modesta, Zizyphus nummularia, Dalbergia sissoo Prosopis glandulosa, Justicia adhatoda, Calotropis procera, Cynodon dactylon and Saccharum bengalensis.* Topping *et al*. (2010) reported that climate and change in landscape structure along with agricultural practices and predation have driven Prey-partridge (*Perdix perdix*) decline.

Among all these threats, predation causes major decline in Grey francolin population in the study area. Predation by hawk was reported prominent; 36% in CSWS and 74% in DDGR during study period. As Grey francolin construct its nest on the ground, so there is more chance of predation as compared to other birds which have their nest on trees or vegetation above ground. Ground nesting birds face more predation especially those living in shrub and grassland habitat (Martin, 1993; Yanes and Suarez, 1995). Potts (1980, 1986), diagnosed that Grey partridge affected by nest predation and shooting, as the abundance of sparrow hawks (*Accipiter nisus* L.) and Common buzzard (*Buteo buteo* L.) has increased in the United Kingdom which causes the partridge decline. Other studies from European countries have shown that the main reasons behind the decline have been a decrease in chick survival through the indirect effects of herbicides decreasing habitat at different stages of the life cycle (Potts, 1986; Rands, 1986), and increased predation rates. Predation is a major factor of partridge mortality in the breeding season in spring/summer especially in areas where there is

little predation control (Bro *et al.,* 2001). A study reported that reduction in predation pressure increased the breeding success and population density of grey partridge (*Perdix perdix)* in Salisbury Plain, England (Tapper *et al.,* 1996). Foxes and partridges had various structural elements at their disposal, in a differentiated landscape which causes partial separation of the predator and its prey in the space (Panek, 2005) while low density of grey partridges coincided with areas of high raptor density (Watson *et al.,* 2007). By controlling predators, providing nesting cover, sufficient insect food for chicks and appropriate rates of shooting (Ewald *et al.,* 2012) can also play an important role in grey partridge conservatıon.

According to present study, being an important habitat of grey francolin, CSWS and DDGR, Salt Range, needs more attention through formulation of an effective conservation plan for the species. Illegal hunting of the species must be strictly prevented through public awareness and also by observing and implementing the Punjab Wildlife Act and Rules 1974. Shooting needs to be regulated by an official body to ensure sustainable harvests of grey francolin in CSWS and DDGR, Salt Range. Wildlife staff should make more efficient and effective efforts for the protection of wildlife in general and Grey francolin in particular to conserve this precious game bird, sustaining its healthy population in this region.

SUMMARY

It is evident from previous research studies that the Grey francolin has suffered significant population declines across its distribution range globally as well as in Pakistan. The present study was conducted on habitat preference, population and breeding aspects of Grey francolin in Salt Range of Punjab, Pakistan. The Salt Range is an east-west trending thrust front in northern Punjab consisting of Jhelum, Chakwal, Khushab and Mianwali districts. It extends between 32º41 - 32º56 N and 71º50 to 74ºE and forms an impressive scarp, from 250m-1520m in elevation. Chumbi Surla Wildlife Sanctuary (CSWS) and Diljabba-Domeli Game Reserve (DDGR) were selected as representative areas of the Salt Range. CSWS is located about 20km south west of Chakwal district at 32º 47 N, 67º 42 E which is heart of the Salt Range at elevation of about 460-1050m. It has significance due to having different habitat types including hills, torrents, wetlands and agriculture lands. Combination of these different ecological zones enabled the sanctuary to support a diversity of fauna. The DDGR is located in Jhelum district at 32° 54N and 73° 09E with 600 m elevation and also part of Salt Range. These areas have dry sub-tropical climate with hot summers and cool winters. The natural vegetation of the both areas is a mixture of sub-tropical semi-evergreen forest and tropical thorn forest.

A reconnaissance survey was conducted to select the study sites within two study areas (CSWS and DDGR). Different types of potential habitat of Grey francolin found in the study area were randomly selected for collecting data including; I)

cultivated crop fields and associated natural vegetation on field boundaries, II) natural forest and associated grassland, III) open lands, and IV) wetlands and associated natural vegetation. To determine the habitat preference of grey francolin, vegetative survey of selected habitat areas were conducted by using quadrate method.

Major plant species present in the study area (CSWS and DDGR) were collected and identified. In total ten quadrates were taken randomly for each plant species like tree, shrub, herb and grasses in each selected habitat. The size of the quadrates was 10m x 10m for trees, 4m x 4m for shrubs and 1m x 1m for grasses and herbs. The density, relative density, frequency, relative frequency and dominance of different plant species were calculated in each selected habitat. Vegetation was analyzed by calculating the Importance Value Index (IVI). Random sampling was used to record different physical parameters within selected habitats such as elevation, slope, aspect, and water availability from study area. The habitat preference of grey francolin was then analyzed by using Ivelv's electivity index (IV).

Grey francolin has got distinct preference for habitat in both study sites in the Salt Range depending upon its requirements. Dominant tree species in all selected habitat were *Acacia modesta, Acacia nilotica, Dalbergia sissoo,* and *Olea Cuspidata* dominant shrub in all habitats was *Ziziphus jujuba* and grasses were *Heteropogon contortus*, *Desmostachya bipinata,* and *Cynodon dactylon.* Plant species used for roosting by Grey francolin included *Acacia modesta, Acacia nilotica* and *Ziziphus jujuba* in CSWS and *Dilbergia sissoo, Acacia modesta* and *Ziziphus jujuba* in DDGR.

In total, 38 plants species were recorded from CSWS; among those seven were trees, five shrubs, fifteen herbs, nine grasses and two cultivated crops. 34 plant species were recorded from DDGR; including six trees, five shrubs, fourteen herbs, seven grasses and two cultivated crops. In CSWS, Grey francolin showed high preference for the habitat having Ivelve's value (IV) of 0.26, elevation of 697 m to 704 m, with slope of 25 º to 55 º, open aspects and where water was available. In DDGR, high preference was shown by Grey francolin for habitat having elevation from 505 m to 523 m with aspect that was not very close and slope of 25 º to 45 º with water availability having Ivelve's value 0.19. The most preferred habitat of Grey francolin found in two study areas (CSWS and DDGR) was natural forest habitat having more trees, shrubs, herbs and grasses and other habitat variables such as elevation, slope and water availability.

For population estimation of Grey francolin in CSWS and DDGR, observations were taken by direct sighting using and vocal calls in four selected habitats in each study site. Forty transects of 0.5 km to 3km in length and 100 m (50 m on each side) in width were established in each habitat type of the both study sites. All transects were taken in scrub zone between elevation of 539m (Khokhar Zer Dam) to 708 m (Dhok Sehla) in CSWS and between 395m (Pathial Pahar) to 505m (Dhial) in DDGR. Transects were walked slowly by single observer to record the grey francolin on or near the line by direct sighting or by listening of their calls. For every direct observation, sighting angle was recorded and perpendicular distance to the francolin was measured both for sighting and calls. For population estimate of Grey francolin by

direct sighting and by calls, the program DISTANCE version 6.0 was used. The following priority models (Key function/ sries expansion) were used to arrive at density estimates: Uniform/cosine, half normal/hermite polynomial, Hazard rate /simple polynomial. Model selection was at the minimum of Akaike information criterion (AIC).

There was significant difference in population densities among different sitesboth by sighting and by calls. In CSWS, population density by sighting was the highest at Openland habitat (3.23 individual ha^{-1}) while lowest at cultivated habitat (1.58 individual ha^{-1})and by calls was the highest at (2.87 individual ha^{-1}) from natural forest habitat, while lowest at (1.59 individual ha^{-1}) from cultivated habitat. In DDGR population density by sighting was highest from wetland (2.47 individual ha^{-1}) and lowest at (2.09 individual ha^{-1}) from natural forest habitat, by calls highest from open land habitat (2.45 individual ha^{-1}) and lowest from wetland habitat (1.10 individual ha^{-1}).

Breeding biology of grey francolin was studied by taking data in transect surveys, which were started before onset of breeding season during March 2011 to September 2012. After locating an active nest (nest with a female, eggs, or fresh droppings was only considered active), it was marked by GPS and allotted a specific number. Marked nests were visited regularly 2-3 times in a week during early morning and late evening after short intervals from egg laying till hatching when nest was visited on daily basis. Data sheets were used to record information such as dates

of laying first and last egg, number of eggs, number of eggs laid or clutch size, date of hatching, number of hatched egg, number of fledgling, shape, color and surface texture of eggs, length, width and volume of the egg, nest location, plant species at nesting site and general appearance or structure of the nest including inner and external diameter**.** One way Analysis of Variance was used by software R 3.0.1 to test whether there were significant differences in physical features of breeding. For categorical measurements of nest and egg, a contingency table was calculated using the software Past 3.

Breeding season of Grey francolin in the study area extended from mid March to end of July. All nests of Grey francolin located during the study were found on the ground in natural vegetation consisting of *Acacia modesta*, *Acacia nilotica*, *Ziziphus jujuba*, *Dalbergia sissoo*, *Desmostachia bipinnata* and *Cynodon dactylon*. Shape of the nest varied from round to oblong in both cultivated and forest habitat. Color of eggs was dusty white to pink with white spots on it, and texture was somewhat rough and smooth, while shape of eggs was oval. There was no difference in the shape of nest (χ^2= 0.28; df = 2; P = 0.87) color of the egg (χ^2= 4.09; df = 3; P = 0.25) and surface texture of the egg (χ^2= 0.623; df = 1; P = 0.43) found from cultivated and natural forest habitats. Mean weight of eggs was 10.39$\pm$0.87 gm (8-14 gm) in forest habitat and13.06$\pm$1.80gm (8-15 gm) in cultivated habitat, mean length was 29.39$\pm$0.93 mm (25-32 mm) in forest habitat and 41.05+3.7 (30-46 mm) in cultivated habitat, mean width was 25.62$\pm$2.11mm (16-35 mm) and mean volume in natural forest habitat was 645.63$\pm$55.24 (425-805 mm2) and in cultivated habitat was 1339.95$\pm$233.27 (653-1671mm^2).

The weight of eggs (ANOVA: F = 2.21; df = 1; P = 0.17) was the same between the habitats; however, egg length (ANOVA: F = 14.439; df = 1; P = 0.005238), egg width (ANOVA: F= 9.7207; df = 1; P = 0.01428) and volume of the eggs (ANOVA: F = 4.09; df = 1; P = 0.18) had higher values in the cultivated habitat.

The mean egg laying period was 12.1±1.20 days (range 7-18 days) and was similar between the habitats (ANOVA: F= 1.2878; df = 1; P = 0.2893). The mean clutch size was 6.8±0.78 (range 4-12 eggs) indicating that this population probably lay eggs on alternate days, with no difference of number of eggs between the habitats (ANOVA: F = 0.499; df =1; P = 0.49). The average incubation period recorded in the present study was 15.7±1.86 (range 13-20 days), similar in both habitats (ANOVA: F = 0.7; df = 1; P = 0.42. Out of a total of 68 eggs recorded in various nests, 53 were hatched (74.80% success) with a mean hatching rate of 5.3±0.85 eggs per clutch and with similar success between the habitats (ANOVA: F = 0.03; df = 1; P = 0.86). The fledging success was estimated at 4.6±0.81 per clutch indicating an overall success of 77%, similar for both habitat types (ANOVA: F = 0.14; df = 1; P = 0.71).

For identification of threats affecting grey francolin's habitat and population, questionnaire survey was conducted. Primary and secondary sources of data were used to collect information in CSWS and DDGR. The surveys were conducted in randomly selected area in both CSWS and DDGR. In total 100 questionnaires were filled, during which different questions were asked from the peoples about population trend, major threats, hunting methods, trade life stage and predator of the grey francolin in study

area. Data was statistically analyzed by using SPSS 16 software to test the hypothesis that all threats e.g., hunting, trade, habitat degradation, predation, livestock pressure, agriculture, fuel wood collection, land clearing and stone crushing, contributed equally or not.

Major threats to grey francolin in both CSWS and DDGR identified by the respondents included; hunting, trade, habitat destruction, predation, livestock pressure, agriculture, fuel wood collection, land clearing and stone crush. In CSWS, contributions of various threats to the Grey francolin ; 38% by illegal hunting , 06% by trade, 06% by habitat destruction, 04% by predation, 04 % by live stock pressure, 18 % by agriculture, 04% by fuel wood collection,18% land clearing and 02% by stone crushing in the protected areas. Similarly, in DDGR are 46% by illegal hunting, 04% by trade, 02% by habitat destruction, 04% by predation, 04 % by live stock pressure, 18 % by agriculture, 16% by fuel wood collection, 04% land clearing and 2% by stone crushing. In CSWS, 36% respondents were in the view that population of grey francolin is increasing after designation of the area as sanctuary, while 38% said that population is declining and, 14 % said that population is stable in sanctuary areas due to control hunting, especially in core zone where all such activities are prohibited.

In DDGR, 30% respondents said that population is increasing, according to 44% population is decreasing, 16 % people said that population is stable in reserve due to controlled hunting and 10% people were unaware. Different hunting methods used for Grey francolin in the study area included; shooting with bore guns, trapping by

setting traps in potential feeding sites of grey francolin, hunting with trained dogs and use of nets.

In CSWS, major hunting method as told by respondents was: 54% shooting, 16% netting and 30% trapping. In DDGR, shooting (58%) was major hunting practice, followed by 28% netting and14 % trapping Trade of grey francolin at different life stages was common in both protected area of CSWS and DDGR causing decline of the species as 6% decline in CSWS and 4% decline in DDGR was recorded. It was recorded that mostly trade occurs at the chick stage as 42% in CSWS and 60% DDGR, than eggs, sub-adult or adult stage. In CSWS, predation caused by different animals by people opinion was: 4% by jackal, 36% by hawk, 28% by mongoose, 6% by snake, 20 % by red fox, 2% by jungle cat and 4% by monitor lizard. In DDGR, 74% by hawk, 10% by mongoose, 4% by snake, and 12% by monitor lizard.

The study concludes that CSWS and DDGR, Salt Range, are potential breeding grounds and habitats of Grey francolin. Present study revealed that Grey francolin was mainly associated with natural vegetation and crop cultivated fields situated around natural vegetation for roosting and breeding in Salt Range. This study emphasizes the need for further research into the aspect of long term monitoring of declines at different scales and determine the feeding habit of grey francolin, so, that it would be helpful in conservation of this precious bird in Salt Range. The study made following recommendation for conservation of Grey francolin in both protected areas.

1. Preferred habitat was natural forest in both CSWS and DDGR, hence, vegetation cover should be improved in Grey francolin habitat and vegetation cutting must be prohibited.
2. Tree species such as *Acacia modesta*, *Acacia nilotica*, and *Dalbergia sissoo* should be maintained in its habitat for roosting.
3. Natural vegetation used by Grey francolin for breeding must also be maintained / improved.
4. Illegal hunting and trade should be strictly controlled through strict implementation of the Punjab Wildlife protection Act 1974.
5. Habitat degradation activities as agricultural intensification/fuel wood collection should be controlled in its habitat.
6. Hunting needs to be regulated by the Punjab Wildlife and Parks Department to ensure sustainable harvests of Grey francolin in the Salt Range.
7. Land encroachment and clearing for the purpose of commercial poultry farming, housing schemes, and other business oriented disturbances must be checked and prohibited.
8. Public awareness must be created among the peoples living in the vicinity of protected areas about the importance / benefits of Grey francolin to communities and threats affecting its populations, which should be ceased.
9. The Salt Range Protection Force in the area should be further strengthened for efficient and effective protection of wildlife in the Salt Range.

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Annexture - I

Interview Performa for Grey Francolin

Form No.

Location: Date:

1. Age:

2. Occupation:

3. Have you seen Grey francolin in your area? A) Yes B) No

If yes?

4. Have you noticed any change in its population?

i. Increase ii. Decrease iii. Stable

5. Do you know what major threats to Grey francolin in this area are?

i. Habitat destruction ii. Illegal Hunting iii. Agricultural practices iv. Grazing Pressure

6. What are different hunting practices in your area?

7. Do people trade grey francolin in breeding season?

8. Do you know about its predator in your area?

9. Do you have any idea how they can be conserved?

Plate 1.1: Pair of Grey Francolin (*Francolinus Pondicerianus*) in Chumbi Surla Wildlife Sanctuary.

Plate 1.2: Chick of Grey Francolin (*Francolinus Pondicerianus*) in Diljabba Domeli Game Reserve.

Plate 3.1: View of Natural Forest Habitat for Grey Francolin in Chumbi Surla Wildlife Sanctuary.

Plate 3.2: View of cultivated crop field habitat for Grey Francolin in Chumbi Surla Wildlife Sanctuary.

Plate 3.3: View of openland habitat for Grey Francolin in Chumbi Surla Wildlife Sanctuary.

Plate 3.4: View of wetland habitat for Grey Francolin in Chumbi Surla Wildlife Sanctuary.

Plate 3.5: View of natural forest habitat for Grey Francolin in Diljabba Domeli Game Reserve.

Plate 3.6: View of cropland habitat for Grey Francolin in Diljabba Domeli Game Reserve.

Plate 3.7: View of openland habitat for Grey Francolin in Diljabba Domeli Game Reserve.

Plate 3.8: View of wetland habitat for Grey Francolin in Diljabba Domeli Game Reserve.

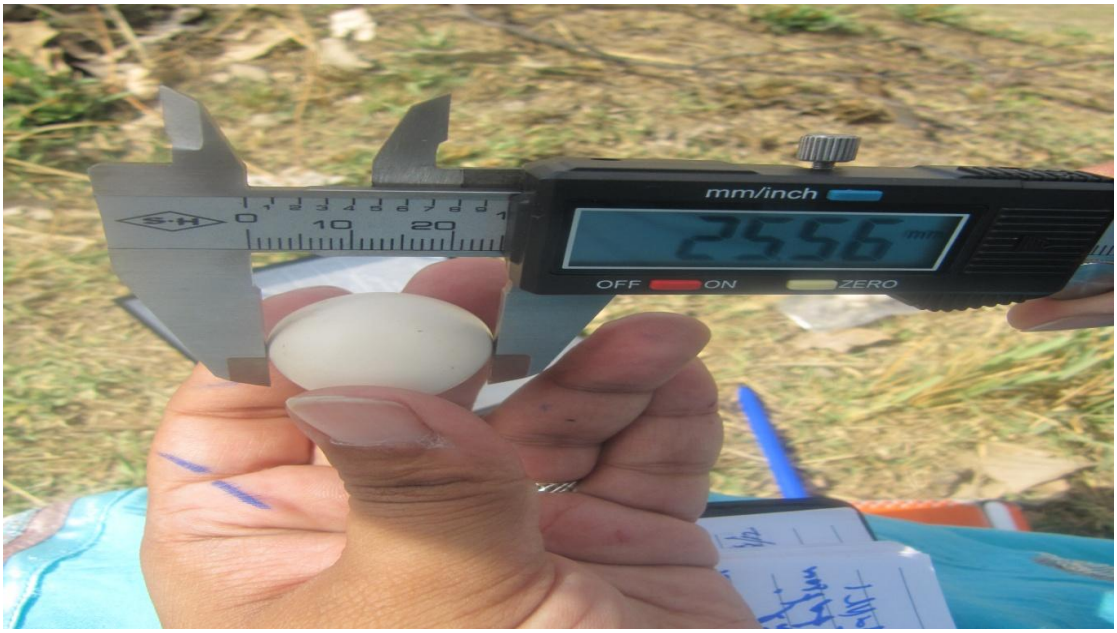

Plate 3.9: Egg measurement by using electronic LCD digital vernier caliper.

Plate 3.10: View of digital scale (SF-820) used to weigh the eggs.

Plate 4.1: Grey Francolin' nest with round shape found in cultivated habitat of Salt Range.

Plate 4.2: Nest with eggs of Grey Francolin found in forest habitat of Salt Range.

Plate 4.3: Pair of Grey Francolin with chicks during feeding in Salt Range.

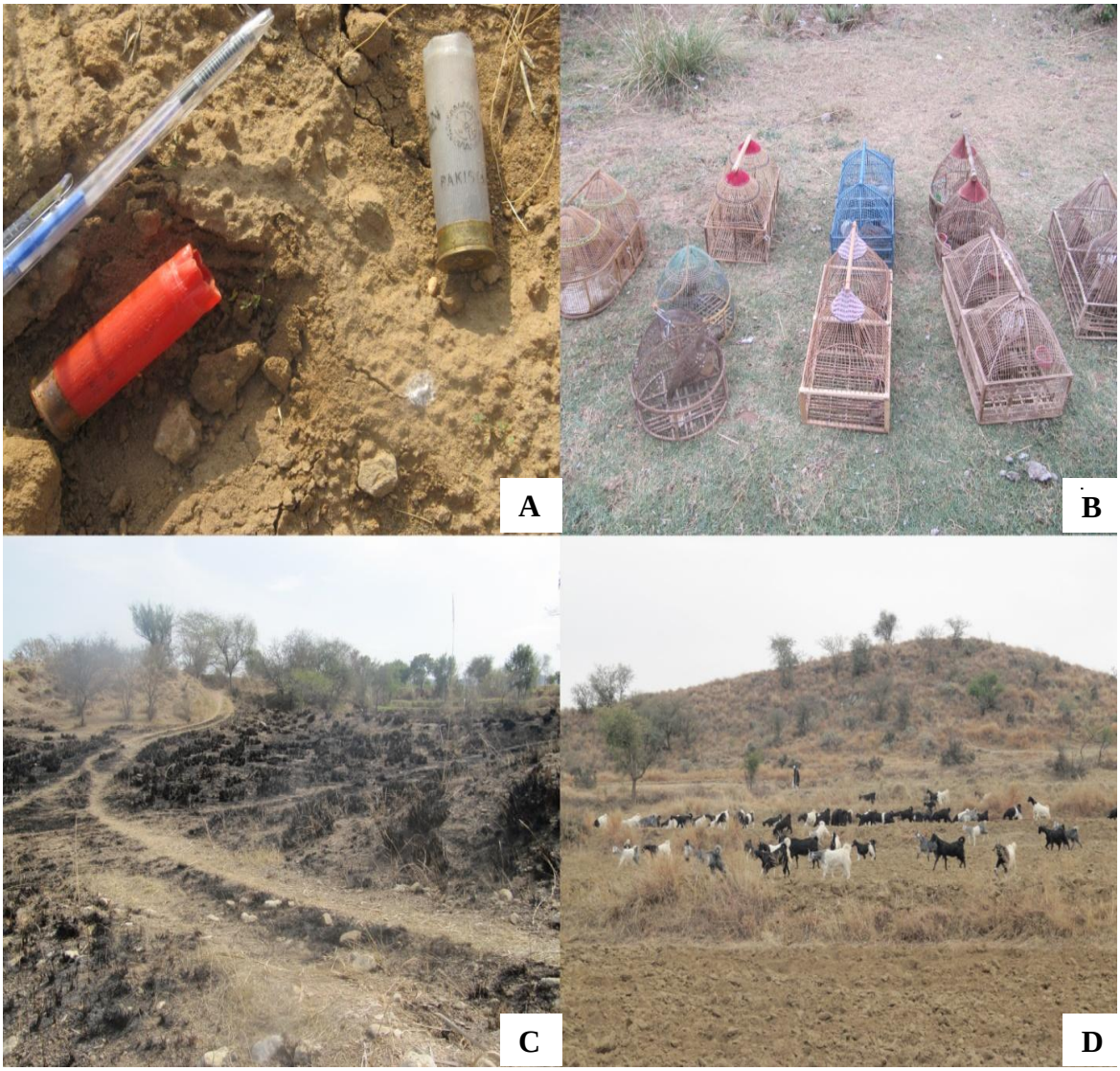

Plate 4.4: View of different threats affecting Grey Francolin in study area of CSWS and DDGR. (A=Hunting with bore guns, B= Trade and Trapping, C=Land Clearing with fire, D=Live Stock Grazing Pressure).